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IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

In re the Application of: Confirmation No.: 6502

Jianzhong ZHANG, *et al.* Art Unit: 2611

Application No.: 10/080,933 Examiner: Jean B. Corrielus

Filed: February 22, 2002 Attorney Dkt. No.: 059864.00665

For: APPARATUS, AND ASSOCIATED METHOD, FOR A MULTIPLE-INPUT, MULTIPLE-OUTPUT COMMUNICATION SYSTEM

PETITION TO THE COMMISSIONER OF PATENTS UNDER 37 C.F.R. §1.182

Mail Stop Petition
Commissioner for Patents
P.O. Box 1450
Alexandria, VA 22313-1450

May 12, 2010

Sir:

Applicants petition the Commissioner for Patents under 37 C.F.R. § 1.182 for withdrawal of the objections to the drawings presented in the Final Office Action dated February 16, 2010 and the Advisory Action dated April 9, 2010.

In the Final Office Action dated February 16, 2010, the Examiner objected to Figures 1-3 under 37 C.F.R. §1.83(a) (*see* Office Action, paragraph 2). The Examiner alleged that the description of Figure 1 does not support the inclusion of a circuit block of "prefilter and feedback filter coefficients calculator." Further, with respect to Figure 2, the Examiner alleged that the input signal 53, input to joint optimizer 74, is not supported by the original disclosure, and therefore should be deleted. The Examiner further alleged that the output of prefilter 56 should feed the DFSE 58, and the DFSE 58 should include an output line. Further, with respect to Figure 3, the Examiner alleged that the input signal 53 to joint optimizer 74 should be removed as the optimizer is described to only receive estimates. Applicants traverse each of these drawing objections for at least the following reasons.

Copies of the Final Office Action, the Advisory Action, Applicants' Response to the Final Office Action, the specification of the above-referenced application, and Figure 1-3, as

presently entered of record, are attached for your convenience and consideration.

With respect to Figure 1, Applicants respectfully submit that one of ordinary skill in the relevant art would have understood that coefficients of the prefilter 56 and the DFSE 58 would have to have been calculated for the prefilter 56 and the DFSE 58 to function. One would have further understood that the calculation of the coefficients of the prefilter 56 and the DFSE 58 occur in the joint optimizer 74, which has been replaced in Figure 1 with the "Prefilter Feedback Filter Coefficients Calculator." Support for these calculations are provided in the specification, at least, on page 17, line 7, to page 18, line 16. Accordingly, sufficient support is provided in Applicants' specification to enable one of ordinary skill in the relevant art to make and/or use the "Prefilter Feedback Filter Coefficients Calculator," as illustrated in Figure 1.

With respect to Figures 2 and 3, Applicants respectfully submit that one of ordinary skill in the relevant art would have understood, from Applicants' specification, at least, on page 17, line 7, to page 18, line 16, that the input signal 53, which is the signal vector y_K, is input into the joint optimizer 74, because it's included in the equation on page 17, line 17, of Applicants' specification. Accordingly, sufficient support is provided in Applicants' specification to enable one of ordinary skill in the relevant art to make and/or use the input signal 53 that is input into the joint optimizer 74," as illustrated in Figures 2 and 3.

In the Advisory Action dated April 9, 2010, the Examiner objected to Figure 2, alleging that the label "FIG. 2" interferes with the drawing. Applicants respectfully traverse this objection because the label does not interfere with any of the elements (boxes, lines, reference numerals) of Figure 2.

Applicants respectfully submit that Figures 1-3 are in compliance with the requirements of 37 C.F.R. §1.83(a). Applicants respectfully submit that the aforementioned drawing objections are in clear error. Reconsideration of Figures 1-3 and withdrawal of the drawing objections, in view of the clear errors in the Final Office Action and the Advisory Action, is respectfully requested. Any fees may be charged to Counsel's Deposit Account 50-2222.

Respectfully submitted,

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BYC:dlh

Enclosures: Office Action dated February 16, 2010
Response dated April 2, 2010
Advisory Action dated April 9, 2010
Specification of the Above-Referenced Application
Figures 1-3, as presently entered of record

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APPLICATION NO.	FILING DATE	FIRST NAMED INVENTOR	ATTORNEY DOCKET NO.	CONFIRMATION NO.
10/080,933	02/22/2002	Jianzhong Zhang	059864.00665	6502

32294 7590 02/16/2010

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14TH FLOOR
VIENNA, VA 22182-6212

EXAMINER	
CORRIELUS, JEAN B	

ART UNIT	PAPER NUMBER
2611	

MAIL DATE	DELIVERY MODE
02/16/2010	PAPER

Please find below and/or attached an Office communication concerning this application or proceeding.

The time period for reply, if any, is set in the attached communication.

Office Action Summary	Application No.	Applicant(s)
	10/080,933	ZHANG ET AL.
	Examiner	Art Unit
	Jean B. Corrielus	2611

OPAP MAY 1 2 2010 PATENT & TRADEMARK OFFICE IAP19

-- The MAILING DATE of this communication appears on the cover sheet with the correspondence address --

Period for Reply

A SHORTENED STATUTORY PERIOD FOR REPLY IS SET TO EXPIRE 3 MONTH(S) OR THIRTY (30) DAYS, WHICHEVER IS LONGER, FROM THE MAILING DATE OF THIS COMMUNICATION.

- Extensions of time may be available under the provisions of 37 CFR 1.136(a). In no event, however, may a reply be timely filed after SIX (6) MONTHS from the mailing date of this communication.
- If NO period for reply is specified above, the maximum statutory period will apply and will expire SIX (6) MONTHS from the mailing date of this communication.
- Failure to reply within the set or extended period for reply will, by statute, cause the application to become ABANDONED (35 U.S.C. § 133). Any reply received by the Office later than three months after the mailing date of this communication, even if timely filed, may reduce any earned patent term adjustment. See 37 CFR 1.704(b).

Status

1)☒ Responsive to communication(s) filed on 30 December 2009.

2a)☒ This action is **FINAL**. 2b)☐ This action is non-final.

3)☐ Since this application is in condition for allowance except for formal matters, prosecution as to the merits is closed in accordance with the practice under *Ex parte Quayle*, 1935 C.D. 11, 453 O.G. 213.

Disposition of Claims

4)☒ Claim(s) 21,23-28,30-33,36-38,40-42,46 and 47 is/are pending in the application.

4a) Of the above claim(s) _____ is/are withdrawn from consideration.

5)☐ Claim(s) _____ is/are allowed.

6)☒ Claim(s) 21,23-28,30-33,36-38, and 40-42, 46-47 is/are rejected.

7)☐ Claim(s) _____ is/are objected to.

8)☐ Claim(s) _____ are subject to restriction and/or election requirement.

Application Papers

9)☐ The specification is objected to by the Examiner.

10)☒ The drawing(s) filed on 15 August 2006 is/are: a)☐ accepted or b)☒ objected to by the Examiner.

Applicant may not request that any objection to the drawing(s) be held in abeyance. See 37 CFR 1.85(a).

Replacement drawing sheet(s) including the correction is required if the drawing(s) is objected to. See 37 CFR 1.121(d).

11)☐ The oath or declaration is objected to by the Examiner. Note the attached Office Action or form PTO-152.

Priority under 35 U.S.C. § 119

12)☐ Acknowledgment is made of a claim for foreign priority under 35 U.S.C. § 119(a)-(d) or (f).

a)☐ All b)☐ Some * c)☐ None of:

1.☐ Certified copies of the priority documents have been received.

2.☐ Certified copies of the priority documents have been received in Application No. _____.

3.☐ Copies of the certified copies of the priority documents have been received in this National Stage application from the International Bureau (PCT Rule 17.2(a)).

* See the attached detailed Office action for a list of the certified copies not received.

Attachment(s)

1) ☒ Notice of References Cited (PTO-892)
2) ☐ Notice of Draftsperson's Patent Drawing Review (PTO-948)
3) ☐ Information Disclosure Statement(s) (PTO/SB/08) Paper No(s)/Mail Date _____.
4) ☐ Interview Summary (PTO-413) Paper No(s)/Mail Date. _____.
5) ☐ Notice of Informal Patent Application
6) ☐ Other: _____.

DETAILED ACTION

Drawings

1. The drawings are objected to under 37 CFR 1.83(a) because they fail to show a signal input to the "joint optimizer", shown in fig. 3 (as described in the specification page 8, lines 15-16, fig. 3 is a block diagram of a portion of the receiving station that forms part of the system shown in fig. 1. Since fig. 3 is a block diagram of a receiving portion of fig. 1, it is not clear how the optimizer 74 shown in fig. 3 is to be connected to existing component(s) of fig. 1 to receive its input). **Shouldn't the specification page 8, lines 15-16, be amended to recite "<u>Figure 3 illustrates the functional block diagram of the joint optimizer, prefilter and decision feedback sequence estimator shown in fig. 3</u>"? <u>Such amendment would overcome the drawing objection</u>.** Any structural detail that is essential for a proper understanding of the disclosed invention should be shown in the drawing. MPEP § 608.02(d). Corrected drawing sheets in compliance with 37 CFR 1.121(d) are required in reply to the Office action to avoid abandonment of the application. Any amended replacement drawing sheet should include all of the figures appearing on the immediate prior version of the sheet, even if only one figure is being amended. The figure or figure number of an amended drawing should not be labeled as "amended." If a drawing figure is to be canceled, the appropriate figure must be removed from the replacement sheet, and where necessary, the remaining figures must be renumbered and appropriate changes made to the brief description of the several views of the drawings for consistency. Additional replacement sheets may be necessary to show the renumbering of the remaining figures. Each

drawing sheet submitted after the filing date of an application must be labeled in the top margin as either "Replacement Sheet" or "New Sheet" pursuant to 37 CFR 1.121(d). If the changes are not accepted by the examiner, the applicant will be notified and informed of any required corrective action in the next Office action. The objection to the drawings will not be held in abeyance.

2. The drawings were received on 12/30/09. These drawings are **not acceptable** because there is no support in the specification as filed for the drawings as now presented. With respect to fig. 1, the description of fig. 1, as filed does not support the inclusion of a circuit block of "prefilter and feedback filter coefficients calculator". With respect to fig. 2, signal **"53",** input to "joint optimizer 74" is not supported by the original disclosure and therefore **should be deleted**. The **output of prefilter 56 should feed the DFSE 58. DFSE 58 should include an output line**. With respect to fig. 3, **remove the input 53 to "joint optimizer 74**", as the optimizer is described to only receive "estimates".

3. Examiner also notes that the amendment is not in accordance with 37 CFR 1.121(d) that states that **any amended replacement drawing sheet should include all of the figures appearing on the immediate prior version of the sheet, even if only one figure is being amended.** In the immediate prior version of the drawing sheets, both figs. 2 and 3 were presented in separate sheets. Accordingly, the replacement sheets have to be presented separately as well.

Examiner's comment

4. Note that claims 38, 40-42 recite means plus function limitations and effectively invoke 112 sixth paragraph. The claims are treated as such.

Claim Objections

5. Claims 26, 28 and 36 are objected to because of the following informalities: claim 26, "signal filter" should be replaced by "prefilter", to be consistent with claim 21, that recites that the "prefilter configured to receive the optimized values", the signal filter does not receive the optimized values.

As per claim 28 some of the limitations recited in the claim are redundant and therefore should be amended as follow to remove the previously recites claim limitations :28 . " The apparatus of claim 25, wherein the optimized values received from the signal optimizer are used to define filter characteristics of the feedback filter".

With respect to claim 36, lines 2-3, does the limitation "the forming" refer to "the forming optimized feedforward filter parameters" and/or "the forming optimized feedback filter parameters" please correct. Appropriate correction is required.

Claim Rejections - 35 USC § 103

6. The following is a quotation of 35 U.S.C. 103(a) which forms the basis for all obviousness rejections set forth in this Office action:

> (a) A patent may not be obtained though the invention is not identically disclosed or described as set forth in section 102 of this title, if the differences between the subject matter sought to be patented and the prior art are such that the subject matter as a whole would have been obvious at the time the invention was made to a person having ordinary skill in the art to which said subject matter pertains. Patentability shall not be negatived by the manner in which the invention was made.

7. Claims 21, 23-26, 28, 30-33, 36, 38, 40-42 and 46-47 are rejected under 35 U.S.C. 103(a) as being unpatentable over Zangi et al US Patent No. 6,775,322 et al. in view of Ketchum et al US Patent No. 6,760,388.

As per claim 21, Zangi et al teaches a receiving station (figs. 1 and 3) comprising a signal filter see col. 3, lines 47-50 inherently in communication with a signal receiving antenna (note fig. 1 is described by Zangi as see col. 3, lines 29-30, as a mobile station therefore it has to include an antenna); a signal estimator 122 in communication with the signal filter see col. 4, lines 57-60; circuit (124) corresponding to the claimed (signal optimizer) configured to generate tap coefficients (optimized values) for the signal from the signal filter ; a prefilter 102 configured to filter the signal from the signal filter using the generated tap coefficients (optimized values) for the signal see col. 4, lines 59-61; circuits (104, 106 and 108) considered as the claimed "decision feedback sequence estimator" to receive the coefficients (optimized values) note input to filter 104, circuit blocks (104, 106 and 108) "decision feedback sequence estimator" comprising a summing element 106, a feedback filter 104 and a maximum likelihood sequence estimator 108, see col. 11, lines 9-12, as shown in fig. 3, Zangi teaches that the summing element 106, the feedback filter 104 and the MLSE 108 are operatively connected to one another and further connected to prefilter 102. Note that the interconnection of the prefilter 102r, the feedback filter 104, the MLSE 108 and the summing element 106 cooperatively operate to permit inherently concurrent interference and prefilter operation to be performed because there is no structural difference between the Zangi's disclosed features of prefilter, the feedback filter, the

MLSE and the summing element and the applicant claimed features of "prefilter, the feedback filter, the MLSE and the summing element". However, Zangi et al does not explicitly teach that the apparatus is a MIMO system having a plurality of signal receivers where concurrent interference and prefilter operation can be performed for a plurality of signals received through said signal receivers. Ketchum et al teaches a MIMO system Fig. 1 having a plurality of signal receivers 154a, 154r Note fig. 1 where concurrent interference and prefilter operation can be performed for a plurality of signals received through said signal receivers using MIMO processor 160 (Note fig. 3 and 5A, for instance). Given that fact, it would have been obvious to one skill in the art to incorporate such a teaching in Zangi in order to improve signal detection since the system would have been able to be configured to receive multiple copies so that existence of signal error can be easily determined.

As per claim 23, Zangi et al teaches that the output of the decision device (MLSE) 108 is configured to transmit generated maximum likelihood values through an output to the feedback filter 104 and the input of the decision device (MLSE) 108 is configured to receive summed values from the summing element 106.

As per claim 24, Zangi et al teaches the feedback filter 104 comprises a first input in communication with circuit 124 (signal optimizer) and configure to receive the optimized values from the circuit 124 (signal optimizer) and a second input configured to receive the generated maximum likelihood values from the MLSE 108.

As per claim 25, Zangi et al further teaches the summing element 106 receives inputs from prefilter 102 and the feedback filter 104 and sends a summed output to the MLSE device 108.

As per claim 26, the signal filter see col. 3, lines 47-50 is located in the forward path of the receiving station hence it has to be a feedforward filter.

As per claim 28, Zangi further teaches that the feedback filter 104 receives optimized signals from the signal optimizer 124 that are used to define filter characteristics of the feedback filter 104 see col. 4, lines 57-60.

As per claim 30, the signal filter see col. 3, lines 47-50 and the signal estimator 122 is placed in the received chain of the receiving station see fig. 1.

As per claim 31, Zangi et al does not teach the further limitations recited in claim 31. Ketchum et al teaches the further limitations of a plurality of receive chains corresponding to the plurality of signal receivers configured to receive and transmit a plurality of data vectors to the plurality of receive chains note fig. 1. Given that fact, it would have been obvious to one skill in the art to incorporate such a teaching in Zangi et al and the motivation to do so would have been the same as provided with respect to claim 21 above.

As per claim 32, see claim 31. In addition, Zangi teaches transmitting the coefficients (optimized feed forward filter parameters and the optimized feedback filter parameters) to a decision feedback sequence estimator (104, 106 and 108), wherein the decision feedback sequence estimator (104, 106 and 108) comprises a feedback filter 104: note that the limitation "simultaneously" is interpreted as "both". Clearly Zangi

teaches that "both" interference cancellation and prefiltering operations are performed via the feedforward filter 102 and the feedback filter 104. See col. 4, lines 43-50. In addition, for the sake of argument, note that the prefiltered signal from feedforward filter 102 is provided as input to the summer 106 at the same time as the ISI compensated signal generated by feedback filter 104 (see col. 7, lines 15-21) another indication that the prefilter and ISI compensation are performed simultaneously.

As per claim 33, Zangi et al further teaches the feedforward filter 102 filters the data vector and transmitting a feedforward output to a summing element 106; receiving an output of the summing element in a MLSE device 108 and generating an output of that is transmitted to an input of the feedback filter 104 and subsequent component and filtering the output received from the MSLE device in the feedback filter 104 and transmitting a filtered signal to the summing element 106.

As per claim 36, Zangi further teaches the received chain comprises a receiving filter see col. 3, lines 47-50 inherently in communication with a signal receiving antenna (note fig. 1 is described by Zangi as see col. 3, lines 29-30, as a mobile station therefore it has to include an antenna); a channel estimator 122 in communication with the receiving filter; the channel estimator 122 in communication with circuit 124 corresponding to the claimed signal optimizer configured to optimized feedforward and feedback filter parameters see col. 5, lines 1-27.

As per claim 38 see rejection of claim 21 above in addition, Zangi et al teaches a receiving station (fig. 1 and 3) comprising receive filter (signal filter means) for filtering a signal from a receiver note col. 3, lines 47-50; a signal estimator means 122 for

estimating channel operations of the signal from the signal filtering means; means 124 corresponding to the claimed signal optimizing means in communication with the signal filtering means for generating coefficients (optimized values); prefiltering means 102 for filtering the signal from the signal filtering means using the generated coefficients (optimized values) means (104, 106 and 108) considered as the claimed "interference cancellation means" for receiving the coefficients (optimized values) to perform concurrent interference and prefilter operations; Zangi further teaches that means (104, 106 and 108) (interference canceling means) comprises summing means 106 for summing inputs from the prefiltering means 102; MLSE means 108 for generating maximum values from the summing means 106; and feedback filtering means 104 for filtering an output of the MLSE 104 based on the generated optimized values to generate feedback-filtered values. Note that the interconnection of the prefiltering means 102, the feedback filtering means 104, the MLSE means 108 and the summing means 106 cooperatively operate to permit inherently concurrent interference and prefilter operation to be performed because there is no structural difference between the Zangi's claimed features of prefiltering means, the feedback filtering means, the MLSE means and the summing means and the applicant claimed features of "prefiltering means , the feedback filtering means, the MLSE means and the summing means.

As per claim 40 see claim 23.

As per claim 41 see claim 24.

As per claim 42, Zangi et al further teaches the summing element 106 receives inputs from prefilter 102 and the feedback filter 104 and sends a summed output to the

MLSE device 108 and an output of the MLSE being an output from the receiving station see fig. 3.

As per claim 46, Zangi teaches that the apparatus is a mobile communication device. See col. 3, lines 29-30.

As per claim 47 the device is inherently an integrated circuit because mobile communication devices uses IC circuit.

8. Claims 27 and 37 are rejected under 35 U.S.C. 103(a) as being unpatentable over Zangi et al US patent No. 6,775,322 in view of in view of Ketchum et al US Patent No. 6,760,388 and further in view of Taylor US Patent Application No. 2002/0197987.

As per claim 27, Zangi et al and Ketchum et al teach every feature of the claimed invention but do not explicitly teach the further limitation of a deinterleaver in communication with an output of the MLSE estimator and depuncture in communication with a deinterleaver and a channel decoder in communication with the deinterleaver. Taylor et al teaches a deinterleaver 58 in communication with an output of the MLSE estimator (i.e. output of demodulator/equalizer 56) and depuncture 62 in communication with a deinterleaver 58 and a channel decoder 64 in communication with the deinterleaver 58. It would have been obvious to one skill in the art to incorporate such a teaching in Zangi et al and Ketchum in order to recover the originally transmitted signal.

As per claim 37, see claim 27.

Examiner's Suggestions and Comment

9. The application includes allowable subject matter, not properly claim. If allowable subject matters are properly claimed, such claims may be given favorable consideration. The combination of fig. 2 and fig. 3, for instance, includes the allowable subject matter that can be incorporated into the claims, such as claim 21, as follow, for favorable consideration:

21. An apparatus, comprising:

a **first** signal filter configured to filter a signal from a **first** signal receiver of a multiple- input, multiple-output system;

a **first** signal estimator configured to estimate channel operations of the signal from the **first** signal filter;

a second signal filter configured to filter a signal from a second signal receiver of the multiple- input, multiple-output system;

a second signal estimator configured to estimate channel operations of the signal from the second signal filter;

a **joint** signal optimizer configured to **receive the channel estimates from the first signal estimator and the second signal estimator and** to generate optimized values for the signal**s** from the **first** signal filter **and the second filter**;

a prefilter configured to filter the signal**s** from the **first** signal filter **and the second signal filter** using the generated optimized values for the signal**s**; and

a decision feedback sequence estimator configured to receive the generated optimized values **and the output of the prefilter**,

wherein the decision feedback sequence estimator comprises a summing element, a feedback filter, and a maximum likelihood sequence estimator, wherein the summing element, the feedback filter, and the maximum likelihood sequence estimator are operatively connected to one another and further operatively connected to the prefilter,

wherein an interconnection of the prefilter, the feedback filter, the maximum likelihood sequence estimator, and the summing element in the apparatus is configured to permit concurrent interference and prefilter operations to be performed for [a plurality of] **the** signals received **from the first signal filter and the second signal filter [by a plurality of signal receivers in the multiple-input, multiple-output system]**.

10. **Note that the claim amendment as proposed above may include informalities and therefore should be reviewed carefully to determine and correct any such informalities.**

Response to Arguments

11. Applicant's arguments filed 12/30/09 have been fully considered but they are not persuasive. Note examiner's comments with respect to the drawing that address much of applicant's comment regarding the same. In addition, Applicant argues that the number of inputs to the optimizer 74 is 2x the number of receive antenna 22. However, it is noted that the number of inputs should be the same as the number of received antennas, note the specification, page 12, lines 10-14. applicant's argument with

respect to Zangi et al, Malkemes and Taylor not disclosing a MIMO system are moot in view of the above new ground of rejection(s). Applicant arguments at pages 17-19 regarding Zangi have been previously addressed, at least in the last office action, and therefore will not be readdressed.

12. Applicant's amendment necessitated the new ground(s) of rejection presented in this Office action. Accordingly, **THIS ACTION IS MADE FINAL**. See MPEP § 706.07(a). Applicant is reminded of the extension of time policy as set forth in 37 CFR 1.136(a).

A shortened statutory period for reply to this final action is set to expire THREE MONTHS from the mailing date of this action. In the event a first reply is filed within TWO MONTHS of the mailing date of this final action and the advisory action is not mailed until after the end of the THREE-MONTH shortened statutory period, then the shortened statutory period will expire on the date the advisory action is mailed, and any extension fee pursuant to 37 CFR 1.136(a) will be calculated from the mailing date of the advisory action. In no event, however, will the statutory period for reply expire later than SIX MONTHS from the date of this final action.

Any inquiry concerning this communication or earlier communications from the examiner should be directed to Jean B. Corrielus whose telephone number is 571-272-3020. The examiner can normally be reached on Monday-Thursday from 9:30-3:00.

If attempts to reach the examiner by telephone are unsuccessful, the examiner's supervisor, Chieh Fan can be reached on 571-272-3042. The fax phone number for the organization where this application or proceeding is assigned is 571-273-8300.

Information regarding the status of an application may be obtained from the Patent Application Information Retrieval (PAIR) system. Status information for published applications may be obtained from either Private PAIR or Public PAIR. Status information for unpublished applications is available through Private PAIR only. For more information about the PAIR system, see http://pair-direct.uspto.gov. Should you have questions on access to the Private PAIR system, contact the Electronic Business Center (EBC) at 866-217-9197 (toll-free). If you would like assistance from a USPTO Customer Service Representative or access to the automated information system, call 800-786-9199 (IN USA OR CANADA) or 571-272-1000.

/Jean B Corrielus/
Primary Examiner, Art Unit 2611

Notice of References Cited	Application/Control No. 10/080,933	Applicant(s)/Patent Under Reexamination ZHANG ET AL.	
	Examiner Jean B. Corrielus	Art Unit 2611	Page 1 of 1

U.S. PATENT DOCUMENTS

*		Document Number Country Code-Number-Kind Code	Date MM-YYYY	Name	Classification
*	A	US-6,760,388	07-2004	Ketchum et al.	375/295
*	B	US-2003/0076908	04-2003	Huang et al.	375/350
*	C	US-2008/0317158	12-2008	Ketchum et al.	375/267
*	D	US-5,550,810	08-1996	Monogioudis et al.	370/342
	E	US-			
	F	US-			
	G	US-			
	H	US-			
	I	US-			
	J	US-			
	K	US-			
	L	US-			
	M	US-			

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FOREIGN PATENT DOCUMENTS

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	N					
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	P					
	Q					
	R					
	S					
	T					

NON-PATENT DOCUMENTS

*		Include as applicable: Author, Title Date, Publisher, Edition or Volume, Pertinent Pages)
	U	
	V	
	W	
	X	

*A copy of this reference is not being furnished with this Office action. (See MPEP § 707.05(a).)
Dates in MM-YYYY format are publication dates. Classifications may be US or foreign.

DO NOT ENTER: /JC/

02/05/2010

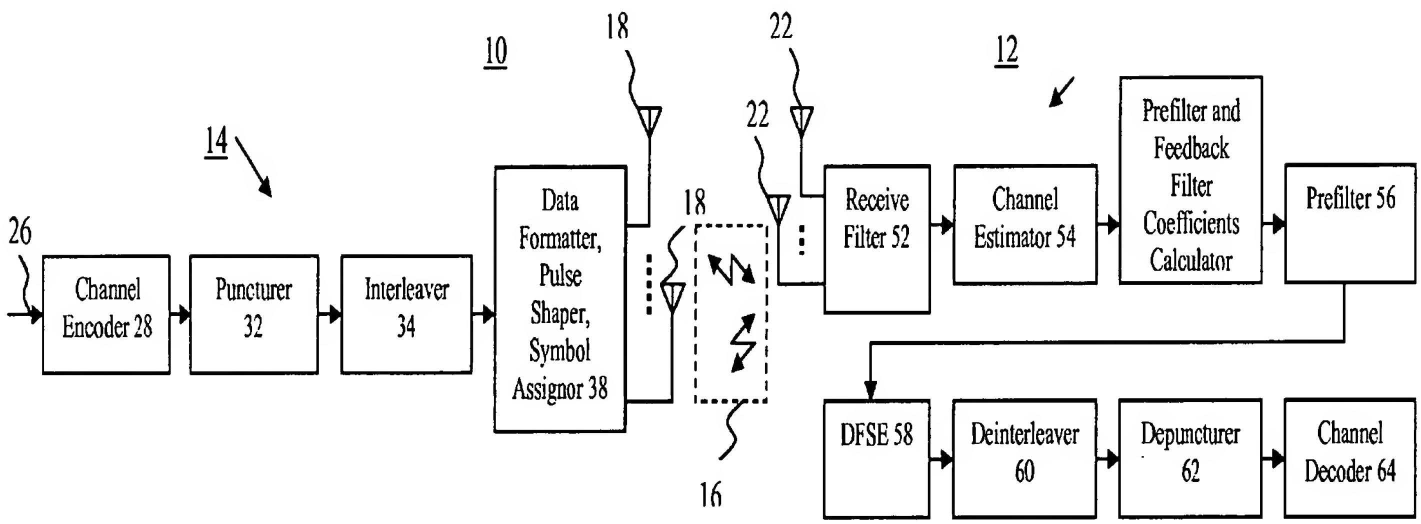

FIG. 1

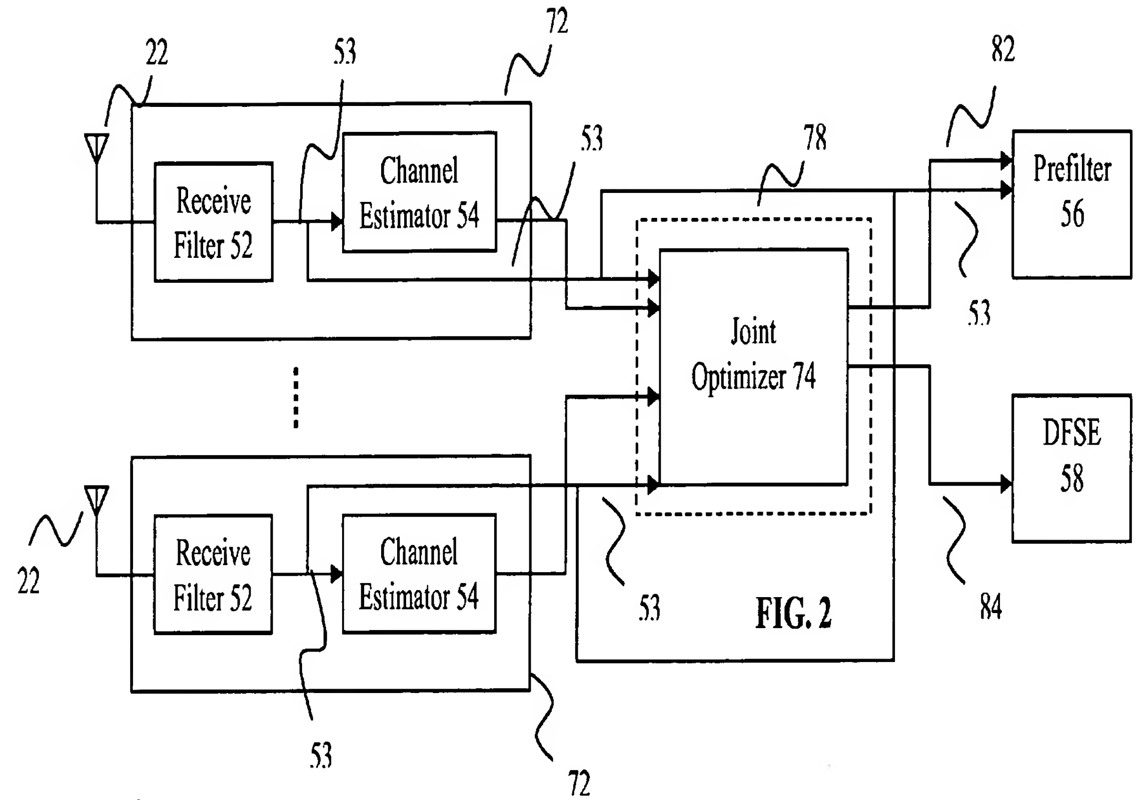
22
53
72
82
Channel Estimator 54
Receive Filter 52
53
78
Prefilter 56
Joint Optimizer 74
53
DFSE 58
Receive Filter 52
Channel Estimator 54
22
53
84
53
72

FIG. 2

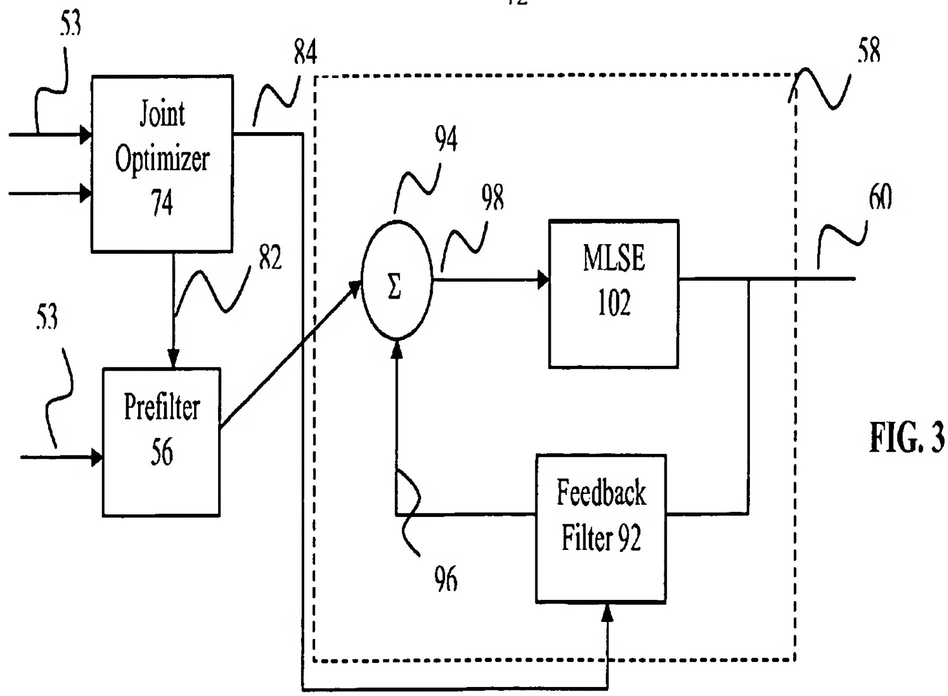
53
84
58
Joint Optimizer 74
94
98
60
Σ
MLSE 102
82
53
Prefilter 56
Feedback Filter 92
96

FIG. 3

EXPEDITED PROCEDURE
EXAMINING GROUP 2600
PATENT APPLICATION

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

In re the Application of:	Confirmation No.: 6502
Jianzhong ZHANG, *et al.*	Art Unit: 2611
Application No.: 10/080,933	Examiner: Jean B. Corrielus
Filed: February 22, 2002	Attorney Dkt. No.: 059864.00665

For: APPARATUS, AND ASSOCIATED METHOD, FOR A MULTIPLE-INPUT, MULTIPLE-OUTPUT COMMUNICATION SYSTEM

RESPONSE UNDER 37 C.F.R. § 1.116

Mail Stop AF
Commissioner for Patents
P.O. Box 1450
Alexandria, VA 22313-1450

April 2, 2010

Sir:

In response to the Office Action dated February 16, 2010, please amend the above-identified application as set forth below.

Amendments to the Drawings are submitted beginning on page 2.

Amendments to the Specification are submitted beginning on page 3.

Amendments to the Claims are submitted beginning on page 4.

Remarks are submitted beginning on page 12.

<u>IN THE DRAWINGS</u>:

Please **AMEND** Figures 2 and 3 as shown in the attached drawing sheets.

IN THE SPECIFICATION:

Please **AMEND** the Specification at page 8, lines 15 and 16 as follows.

-- Figure 3 illustrates a functional block diagram of a joint optimizer, prefilter, and decision feedback sequence estimator that forms part of the communication system shown in Figure 1. --

IN THE CLAIMS:

Please **AMEND** claims 26, 28, and 36 as follows.

1-20. (Cancelled)

21. (Previously Presented) An apparatus, comprising:

a signal filter configured to filter a signal from a signal receiver of a multiple-input, multiple-output system;

a signal estimator configured to estimate channel operations of the signal from the signal filter;

a signal optimizer configured to generate optimized values for the signal from the signal filter;

a prefilter configured to filter the signal from the signal filter using the generated optimized values for the signal; and

a decision feedback sequence estimator configured to receive the generated optimized values, wherein the decision feedback sequence estimator comprises a summing element, a feedback filter, and a maximum likelihood sequence estimator,

wherein the summing element, the feedback filter, and the maximum likelihood sequence estimator are operatively connected to one another and further operatively connected to the prefilter,

wherein an interconnection of the prefilter, the feedback filter, the maximum likelihood sequence estimator, and the summing element in the apparatus is configured to permit concurrent interference and prefilter operations to be performed for a plurality of signals received by a plurality of signal receivers in the multiple-input, multiple-output system.

22. (Cancelled)

23. (Previously Presented) The apparatus of claim 21, wherein the maximum likelihood sequence estimator is configured to transmit generated maximum-likelihood values through an output to the feedback filter, and wherein an input of the maximum likelihood sequence estimator is configured to receive summed values from the summing element.

24. (Previously Presented) The apparatus of claim 23, wherein the feedback filter comprises a first input configured to receive the optimized values from the signal optimizer and a second input configured to receive the generated maximum-likelihood values from the maximum likelihood sequence estimator.

25. (Previously Presented) The apparatus of claim 24, wherein the summing element is further configured to receive inputs from the prefilter and the feedback filter

and is further configured to send a summed output to the maximum likelihood sequence estimator.

26. (Currently Amended) The apparatus of claim 21, wherein the ~~signal~~ <u>pre</u>filter comprises a feed forward filter.

27. (Previously Presented) The apparatus of claim 25, further comprising:

a de-interleaver configured to de-interleave the signal from an output of the maximum likelihood sequence estimator;

a de-punctuator configured to de-puncture the signal from the de-interleaver; and

a channel decoder configured to decode the signal from the de-interleaver.

28. (Currently Amended) The apparatus of claim ~~25~~<u>24</u>, wherein the feedback filter is further configured to receive <u>the </u>optimized signals from the signal optimizer that are used to define filter characteristics of the feedback filter.

29. (Cancelled)

30. (Previously Presented) The apparatus of claim 21, wherein the signal filter and the signal estimator comprise a receive chain.

31. (Previously Presented) The apparatus of claim 30, wherein the apparatus comprises a plurality of receive chains corresponding to a plurality of signal receivers configured to receive and transmit a plurality of signal data vectors to the plurality of receive chains.

32. (Previously Presented) A method, comprising:

receiving a data vector at a receiving station of a multiple-input, multiple-output system;

forming optimized feed forward filter parameters from the data vector;

forming optimized feedback filter parameters from the data vector;

transmitting the optimized feed forward filter parameters and the optimized feedback filter parameters to a decision feedback sequence estimator, wherein the decision feedback sequence estimator comprises a feedback filter;

applying the optimized feed forward filter parameters to a feed forward filter to define filter characteristics of the feed forward filter;

applying the optimized feedback filter parameters to the feedback filter to define filter characteristics of the feedback filter; and

simultaneously performing interference cancellation and pre-filtering operations on the data vector through operation of the feed forward and feedback filters,

wherein receiving the data vector comprises receiving a plurality of data vectors on a corresponding plurality of receiving chains at the receiving station of the multiple-input, multiple-output system.

33. (Previously Presented) The method of claim 32, wherein simultaneously performing interference cancellation and pre-filtering operations comprises:

filtering the data vector with the feed forward filter and transmitting a feed forward filter output to a summing element;

receiving an output of the summing element in a maximum likelihood sequence estimator and generating an output that is transmitted to an input of the feedback filter and to a subsequent component; and

filtering the output received from the maximum likelihood sequence estimator in the feedback filter and transmitting a filtered signal to the summing element.

34-35. (Cancelled)

36. (Currently Amended) The method of claim 32, wherein the receiving is conducted by a receiving filter in communication with a signal receiver; and wherein the forming the optimized feed forward filter parameters and the forming the optimized feedback filter parameters are ~~is~~ conducted by a channel estimator in communication with the receiving filter, the channel estimator being in communication with an optimizer

configured to generate the optimized feed forward filter parameters and the optimized feedback filter parameters.

37. (Previously Presented) The method of claim 33, wherein the subsequent component comprises a de-interleaver, a de-punctuator, and a channel decoder.

38. (Previously Presented) An apparatus, comprising:

signal filtering means for filtering a signal from a signal receiver of a multiple-input, multiple-output system;

signal estimating means for estimating channel operations of the signal from the signal filtering means;

signal optimizing means for generating optimized values for the signal from the signal filtering means;

prefiltering means for filtering the signal from the signal filtering means using the generated optimized values for the signal; and

interference cancelling means for receiving the generated optimized values to perform concurrent interference and prefilter operations,

wherein the interference cancelling means comprises

summing means for summing inputs from the prefilter means;

maximum likelihood sequence estimating means for generating maximum-likelihood values from the summing means; and

feedback filtering means for filtering an output of the maximum likelihood sequence estimating means based on the generated optimized values to generate feedback-filtered values,

wherein an interconnection of the prefiltering means, the feedback filtering means, the maximum likelihood sequence estimating means, and the summing means in the apparatus is configured to permit the concurrent interference and prefilter operations to be performed for a plurality of signals received by a plurality of signal receivers in the multiple-input, multiple-output system.

39. (Cancelled)

40. (Previously Presented) The apparatus of claim 38, wherein the maximum likelihood sequence estimating means is further for transmitting the generated maximum-likelihood values through an output to the feedback filtering means, and wherein an input of the maximum likelihood sequence estimating means is further for receiving summed values from the summing means.

41. (Previously Presented) The apparatus of claim 40, wherein the feedback filtering means comprises a first input configured to receive the optimized values from the signal optimizing means and a second input configured to receive the generated maximum-likelihood values from the maximum likelihood sequence estimating means.

42. (Previously Presented) The apparatus of claim 41, wherein the summing means is further for receiving inputs from the prefiltering means and the feedback filtering means and is further for sending a summed output to the maximum likelihood sequence estimating means, an output of the maximum likelihood sequence estimating means being an output from the apparatus.

43-45. (Cancelled)

46. (Previously Presented) The apparatus of claim 21, wherein the apparatus is a mobile communications device.

47. (Previously Presented) The apparatus of claim 21, wherein the apparatus is an integrated circuit.

I. REMARKS

The Office Action dated February 16, 2010, has been received and carefully noted. The above amendments to the specification, drawings, and claims, and the following remarks, are submitted as a full and complete response thereto.

By this Response, Figures 2 and 3 and the specification at page 8, lines 15 and 16 have been amended to overcome the objections to the drawings. Claims 26, 28, and 36 have been amended to more particularly point out and distinctly claim the subject matter of the invention. No new matter has been added. Support for the above amendments is provided in the specification, at least, on page 9, line 15, to page 20, line 10. Accordingly, claims 21, 23-28, 30-33, 36-38, 40-42, and 46-47 are currently pending in the application, of which claims 21, 32, and 38 are independent claims. Applicants request entry of the above amendments because the above amendments place the figures, the specification, and the claims in better condition for issuance.

Applicants thank the Examiner for indicating that embodiments of the invention contain allowable subject matter as illustrated in Figures 2 and 3 (*see* Office Action on pages 10-12). Applicants further thank the Examiner for proposing amendments to claim 21.

In view of the above amendments and the following remarks, Applicants respectfully request reconsideration and timely withdrawal of the pending rejections to the claims for the reasons discussed below.

(A) *Drawing Objections under 37 C.F.R. §1.83(a)*

The drawings were objected to under 37 C.F.R. §1.83(a) because Figure 3 allegedly fails to illustrate a signal input to the "joint optimizer," as described in the specification on page 8, lines 15-16. The Office Action alleged that Figure 3 is a block diagram of a portion of the receiving station that forms part of the system shown in Figure 1. The Office Action further alleged that, since Figure 3 is a block diagram of a receiving portion of Figure 1, it is allegedly not clear how the optimizer 74 shown in Figure 3 is to be connected to existing component(s) of Figure 1 to receive it's input. The Office Action recommended amending the specification to recite, "Figure 3 illustrates the functional block diagram of the joint optimizer, prefilter and decision feedback sequence estimator shown in Fig. 3" (*see* Office Action on pages 2 and 3).

Accordingly, Applicants have amended the specification at page 8, lines 15 and 16, as recommended in the Office Action.

The Office Action also objected to the drawings because there is allegedly no support in the specification for the drawings, as amended in Applicants' Response filed December 30, 2009. Specifically, the Office Action alleged that the description of Figure 1 does not support the inclusion of a circuit block of "prefilter and feedback filter coefficients calculator." Further, with respect to Figure 2, the Office Action alleged that the input signal 53, input to joint optimizer 74, is not supported by the original disclosure, and therefore should be deleted. The Office Action further alleged that the output of prefilter 56 should feed the DFSE 58, and the DFSE 58 should include an output line.

Further, with respect to Figure 3, the Office Action alleged that the input signal 53 to joint optimizer 74 should be removed as the optimizer is described to only receive estimates.

Applicants respectfully traverse the objection to the drawing for Figure 1. Applicants respectfully submit that one of ordinary skill in the relevant art would have understood that coefficients of the prefilter 56 and the DFSE 58 would have to have been calculated for the prefilter 56 and the DFSE 58 to function. One would have further understood that the calculation of the coefficients of the prefilter 56 and the DFSE 58 occur in the joint optimizer 74, which has been replaced in Figure 1 with the "Prefilter Feedback Filter Coefficients Calculator." Support for these calculations are provided in the specification, at least, on page 17, line 7, to page 18, line 16. Accordingly, sufficient support is provided in Applicants' specification to enable one of ordinary skill in the relevant art to make and/or use the "Prefilter Feedback Filter Coefficients Calculator," as illustrated in Figure 1.

Applicants respectfully traverse the objections to the drawings for Figures 2 and 3 related to the input signal 53 input into the joint optimizer 74. Applicants respectfully submit that one of ordinary skill in the relevant art would have understood, from Applicants' specification, at least, on page 17, line 7, to page 18, line 16, that the input signal 53, which is the signal vector y_K, is input into the joint optimizer 74, because it's included in the equation on page 17, line 17, of Applicants' specification. Accordingly, sufficient support is provided in Applicants' specification to enable one of ordinary skill

in the relevant art to make and/or use the input signal 53 that is input into the joint optimizer 74," as illustrated in Figures 2 and 3.

As recommended in the Office Action, Applicants have amended Figure 3 to illustrate that the output of the prefilter 56 is fed into the DFSE 58 and an output line from the DFSE 58. As further recommended in the Office Action, Applicants have provided separate replacement sheets for the drawings for Figures 2 and 3.

Therefore, Applicants respectfully request withdrawal of the objections to the drawings. Applicants respectfully submit that the drawings are now in condition for issuance.

(B) ***Objections to the Claims***

The Office Action objected to claims 26, 28, and 36 because of minor informalities. In particular, the Office Action alleged that in claim 26 "signal filter" should be replaced with "prefilter" to be consistent with claim 21. The Office Action alleged that in claim 28 redundant limitations should be omitted. The Office Action also alleged that in claim 36, at lines 2 and 3, clarification should be made as to whether the limitation "the forming" refers to "the forming optimized feedforward filter parameters" and/or "the forming optimized feedback filter parameters."

Accordingly, Applicants have amended claims 26, 28, and 36 to more particularly point out and distinctly claim the subject matter of the invention, as recommended in the Office Action.

Therefore, Applicants respectfully request withdrawal of the objections of claims 26, 28, and 36. Applicants respectfully submit that claims 26, 28, and 36 are in condition for allowance.

(C) *Claim Rejections under 35 U.S.C. §103(a)*

The Office Action rejected claims 21, 23-26, 28, 30-33, 36, 38, 40-42, 46, and 47 under 35 U.S.C. §103(a) as being allegedly unpatentable over Zangi in view of Ketchum. The Office Action alleged that Zangi discloses every element recited in the pending claims with the exception of a multiple-input, multiple-output (MIMO) system having a plurality of signal receivers where concurrent interference and prefilter operation can be performed for a plurality of signals received through the signal receivers. The Office Action alleged that Ketchum cures the deficiencies of Zangi. Applicants respectfully submit that the claims recite subject matter that is neither described nor suggested in a combination of Zangi and Ketchum.

Claim 21, upon which claims 23-28, 30-31, and 46-47 depend, recites an apparatus. The apparatus includes a signal filter configured to filter a signal from a signal receiver of a multiple-input, multiple-output system, and a signal estimator configured to estimate channel operations of the signal from the signal filter. The apparatus also includes a signal optimizer configured to generate optimized values for the signal from the signal filter, a prefilter configured to filter the signal from the signal filter using the generated optimized values for the signal, and a decision feedback sequence estimator configured to receive the generated optimized values. The decision feedback sequence

estimator includes a summing element, a feedback filter, and a maximum likelihood sequence estimator. The summing element, the feedback filter, and the maximum likelihood sequence estimator are operatively connected to one another and further operatively connected to the prefilter. An interconnection of the prefilter, the feedback filter, the maximum likelihood sequence estimator, and the summing element in the apparatus is configured to permit concurrent interference and prefilter operations to be performed for a plurality of signals received by a plurality of signal receivers in the multiple-input, multiple-output system.

Claim 32, upon which claims 33, 36, and 37 depend, recites a method. The method includes receiving a data vector at a receiving station of a multiple-input, multiple-output system, forming optimized feed forward filter parameters from the data vector, and forming optimized feedback filter parameters from the data vector. The method further includes transmitting the optimized feed forward filter parameters and the optimized feedback filter parameters to a decision feedback sequence estimator. The decision feedback sequence estimator includes a feedback filter. Further, the method includes applying the optimized feed forward filter parameters to a feed forward filter to define filter characteristics of the feed forward filter, and applying the optimized feedback filter parameters to the feedback filter to define filter characteristics of the feedback filter. The method also includes simultaneously performing interference cancellation and pre-filtering operations on the data vector through operation of the feed forward and feedback filters. Receiving the data vector includes receiving a plurality of

data vectors on a corresponding plurality of receiving chains at the receiving station of the multiple-input, multiple-output system.

Claim 38, upon which claims 40-42 depend, recites an apparatus. The apparatus includes signal filtering means for filtering a signal from a signal receiver of a multiple-input, multiple-output system, and signal estimating means for estimating channel operations of the signal from the signal filter means. The apparatus also includes signal optimizing means for generating optimized values for the signal from the signal filtering means, prefiltering means for filtering the signal from the signal filtering means using the generated optimized values for the signal and interference cancelling means for receiving the generated optimized values to perform concurrent interference and prefilter operations. The interference cancelling means includes pre-filtering means, summing means for summing inputs from the prefilter means, feedback filtering means for filtering optimized values and a summed output from the signal optimizing means and the summing means, respectively, and maximum likelihood sequence estimating means for generating maximum-likelihood values from the summing means. An interconnection of the pre-filtering means, the feedback filtering means, the maximum likelihood sequence estimating means, and the summing means in the apparatus is configured to permit the concurrent interference and prefilter operations to be performed for a plurality of signals received by a plurality of signal receivers in the multiple-input, multiple-output system.

Applicants respectfully submit that certain embodiments of the invention provide non-obvious advantages. Specifically, certain embodiments of the invention relate to a

MIMO communication system, whereby interference cancellation and equalization pre-filtering operations at a receiving station of the MIMO communication system are performed. Hence, the system includes a joint encoder, a MIMO transmission, and a MIMO receiver.

As will be discussed below, a combination of Zangi and Ketchum fails to disclose or suggest every element recited in claims 21, 23-26, 28, 30-33, 36, 38, 40-42, 46, and 47, and therefore fails to provide the advantages and the features of the claims discussed above.

Zangi is directed to a method for computing a coefficient of a finite impulse response pre-filter applied prior to a decision algorithm in an equalizer having adjustable filter coefficients. Computations performed to compute the filter coefficients for a right half burst may be used to compute the prefilter for a left hand burst, reducing the number of computations. A square root-free algorithm may be used to solve the system of linear equations, reducing computational complexity (Zangi, col. 2, lines 8-39).

Ketchum is directed to a time-domain transmit and receive processing with channel eigenmode decomposition for MIMO systems. Ketchum discusses techniques for processing a data transmission at a transmitter and receiver. A time-domain implementation is provided in Ketchum that uses frequency-domain singular value decomposition and "water-pouring" results to derive time-domain pulse-shaping and beam-steering solutions at the transmitter and receiver. The singular value decomposition is performed at the transmitter to determine eigenmodes (*e.g.*, spatial

subchannels) of a MIMO channel and to derive a first set of steering vectors used to "precondition" the received signals so that orthogonal symbol streams are recovered at the receiver. Water-pouring analysis is used to more optimally allocate the total available transmit power to the eigenmodes, which then determines the data rate and the coding and modulation scheme to be used for each eigenmode (Ketchum, col. 2, line 25, to col. 3, line 10).

As discussed in Applicants' Response dated December 30, 2009, Zangi fails to disclose or suggest, at least, "a signal filter configured to filter a signal <u>from a signal receiver of a multiple-input, multiple-output system</u>" and "wherein an interconnection of the prefilter, the feedback filter, the maximum likelihood sequence estimator, and the summing element in the apparatus is configured to permit concurrent interference and prefilter operations to be performed <u>for a plurality of signals received by a plurality of signal receivers in the multiple-input, multiple-output system</u>," as recited in claim 21 (emphasis added), and similarly recited in claims 32 and 38.

Zangi fails to mention either feature associated with a multiple-input, multiple-output system. Zangi is specifically related to a system including a single transmitter and a single receiver.

Furthermore, contrary to the Office Action's allegations, Zangi also fails to describe "a decision feedback sequence estimator <u>configured to receive the generated optimized values</u>, wherein the decision feedback sequence estimator comprises a

summing element, a feedback filter, and a maximum likelihood sequence estimator," as recited in claim 21 (emphasis added), and similarly recited in claims 32 and 38.

The Office Action grouped the feedback filter 104, the summer 106, and the decision algorithm 108 described in Zangi to allege that Zangi describes the "decision feedback sequence estimator" recited in the pending claims (*see* Office Action, page 5, "circuits (104, 106, and 108) [are] considered as the claimed "decision feedback sequence estimator" to receive the coefficients (optimized values), note input to filter 104). However, a review of Zangi demonstrates that Zangi fails to disclose or suggest every element recited in the pending claims.

Zangi explicitly describes an equalizer 100, which may be a decision feedback equalizer (DFE) or a decision feedback sequence estimation (DFSE) equalizer. Equalizer 100 includes an equalization filter 101, *a decision algorithm 108*, and a processor 120. Equalization filter 101 includes a prefilter 102, *a feedback filter 104*, and *a summer 106*. Processor 120 includes a channel estimator 122 and an adaptive algorithm 124 (Zangi, Figures 1 and 3; col. 3, line 29, to col. 4, line 60). Thus, equalizer 100, which Zangi explicitly describes as a DFSE, includes a feedback filter 104, a summer 106, and a decision algorithm 108, *i.e.*, all three structural elements are contained <u>within</u> the DFSE 100 (*see* Zangi, Figure 3).

Zangi further explicitly describes that <u>DFSE 100 includes the pre-filter 102, the channel estimator 122, and the adaptive algorithm 124</u>, *i.e.*, the pre-filter 102, the channel estimator 122, and the adaptive algorithm 124 are also contained <u>within</u> the DFSE 100.

Accordingly, one of ordinary skill in the relevant art would have understood that the DFSE 100 is not "configured to receive the generated optimized values" (emphasis added), rather, the optimized values are generated within the DFSE 100. DFSE 100 only receives the "received sequence, *r(k)*."

Applicants respectfully submit that the Office Action improperly re-grouped the elements of the DFSE 100, as described in Zangi, to exclude the processor 120, so that the "optimized values" generated within the adaptive algorithm 124 could be received within the newly grouped DFSE (only including the feedback filter 104, the summer 106, and the decision algorithm 108). As previously noted, Zangi explicitly describes that the DFSE includes the processor 120, the channel estimator 122, and the adaptive algorithm 124, and therefore the optimized values are generated within the DFSE 100, not received by the DFSE 100.

Accordingly, Zangi fails to describe or suggest, at least, "a decision feedback sequence estimator configured to receive the generated optimized values, wherein the decision feedback sequence estimator comprises a summing element, a feedback filter, and a maximum likelihood sequence estimator," as recited in claim 21 (emphasis added), and similarly recited in claims 32 and 38.

Applicants respectfully submit that one of ordinary skill in the relevant art would not have found it obvious to combine Zangi with Ketchum. The Office Action alleged that it would have been obvious to combine Zangi and Ketchum to improve signal detection since the system would have been able to be configured to receive multiple

copies so that existence of signal error can be easily determined (*see* Office Action on page 6). Applicants respectfully disagree with the allegations presented in the Office Action.

One of ordinary skill in the relevant art would have understood that the fundamental differences between the features for the system discussed in Ketchum and the features of the system discussed in Zangi would have made it non-obvious to combine Zangi and Ketchum. For example, Ketchum discusses applying singular value decomposition (SVD) to derive time-domain *pulse-shaping* and *beam steering* solutions at a transmitter. Additionally, Ketchum discusses the application of the SVD at the receiver to restore orthogonality (*see*, for example, the abstract of Ketchum) of the orthogonal symbol streams. Embodiments of the invention are not directed, nor require, *pulse-shaping*, *beam steering*, or orthogonal symbol streams. One would have concluded that these fundamental differences between Zangi and Ketchum demonstrate that a combination of Zangi and Ketchum would not have been obvious. Furthermore, one of ordinary skill in the relevant art would have understood that such a combination of Zangi and Ketchum would render Zangi unsatisfactory for its intended purpose.

Assuming *arguendo*, however, that Zangi could be combined with Ketchum, the combination of Zangi and Ketchum fails to disclose or suggest, at least, "a decision feedback sequence estimator <u>configured to receive the generated optimized values</u>, wherein the decision feedback sequence estimator comprises a summing element, a feedback filter, and a maximum likelihood sequence estimator" and "a decision feedback

sequence estimator <u>configured to receive the generated optimized values</u>, wherein the decision feedback sequence estimator comprises a summing element, a feedback filter, and a maximum likelihood sequence estimator," as recited in claim 21 (emphasis added), and similarly recited in claims 32 and 38. Thus, assuming *arguendo* that Zangi could be combined with Ketchum, the combination of Zangi and Ketchum fails to disclose or suggest every element recited in claims 21, 32, and 38.

Therefore, Applicants respectfully request withdrawal of the rejections of claims 21, 23-26, 28, 30-33, 36, 38, 40-42, 46, and 47 under 35 U.S.C. §103(a). Applicants respectfully submit that claims 21, 32, and 38, and the claims that depend therefrom, are in condition for allowance.

The Office Action rejected claims 27 and 37 under 35 U.S.C. §103(a) as being allegedly unpatentable over Zangi in view of Ketchum, and further in view of Taylor. The Office Action alleged that the combination of Zangi and Ketchum discloses every element recited in independent claims 21 and 32. The Office Action referred Taylor to disclose the elements recited in dependent claims 27 and 37. Applicants respectfully submit that the claims recite subject matter that is neither described nor suggested in a combination of Zangi, Ketchum, and Taylor.

Zangi and Ketchum were discussed above. Taylor is directed to a transparent data transmission for a wireless/cellular communication system. An analog signal from a modem or other source is converted at a remote station to a digital bit stream in

accordance with a memoryless compaction rule. The resultant bit stream is then transmitted through a transparent channel that includes a wireless cellular-telephone link. At the base station, that bit stream is transmitted over a public-switched-network span (Taylor, paragraphs [0003]-[0005]).

As previously noted, one of ordinary skill in the relevant art would not have found it obvious to combine Zangi and Ketchum. Assuming *arguendo*, however, that Zangi could be combine with Ketchu, the combination of Zangi and Ketchum fails to disclose or suggest every element recited in claims 21 and 32. Taylor fails to cure the deficiencies of Zangi and Ketchum. Specifically, Taylor fails to disclose or suggest, at least, "a signal filter configured to filter a signal <u>from a signal receiver of a multiple-input, multiple-output system</u>" and "wherein an interconnection of the prefilter, the feedback filter, the maximum likelihood sequence estimator, and the summing element in the apparatus is configured to permit concurrent interference and prefilter operations to be performed <u>for a plurality of signals received by a plurality of signal receivers in the multiple-input, multiple-output system</u>," "a decision feedback sequence estimator <u>configured to receive the generated optimized values</u>, wherein the decision feedback sequence estimator comprises a summing element, a feedback filter, and a maximum likelihood sequence estimator" and "a decision feedback sequence estimator <u>configured to receive the generated optimized values</u>, wherein the decision feedback sequence estimator comprises a summing element, a feedback filter, and a maximum likelihood sequence estimator," as recited in claim 21 (emphasis added), and similarly recited in claim 32. Accordingly, the

assuming *arguendo* that Zangi could be combined with Ketchum and Taylor, the combination of Zangi, Ketchum, and Taylor fails to disclose or suggest every element recited in claims 21 and 32.

Claims 27 and 37 depend from claims 21 and 32, respectively. Accordingly, claims 27 and 37 should be allowable for at least their dependency upon an allowable base claim, and for the specific limitations recited therein.

Therefore, Applicants respectfully request withdrawal of the rejections of claims 27 and 37 under 35 U.S.C. §103(a). Applicants respectfully submit that claims 21 and 32, and the claims that depend therefrom, are in condition for allowance.

II. CONCLUSION

In conclusion, Applicant respectfully submits that each of Zangi, Ketchum and Taylor, whether taken individually or in combination, fails to describe or suggest each and every feature recited in claims. The distinctions previously noted are more than sufficient to render the claimed invention non-obvious. It is therefore respectfully requested that all of claims be allowed, and this present application be passed to issuance.

If for any reason the Examiner determines that the application is not now in condition for allowance, it is respectfully requested that the Examiner contact, by telephone, Applicants' undersigned representative at the indicated telephone number to arrange for an interview to expedite the disposition of this application.

In the event this paper is not being timely filed, Applicants respectfully petition for an appropriate extension of time. Any fees for such an extension together with any additional fees may be charged to Counsel's Deposit Account 50-2222.

Respectfully submitted,

/Brad Y. Chin/

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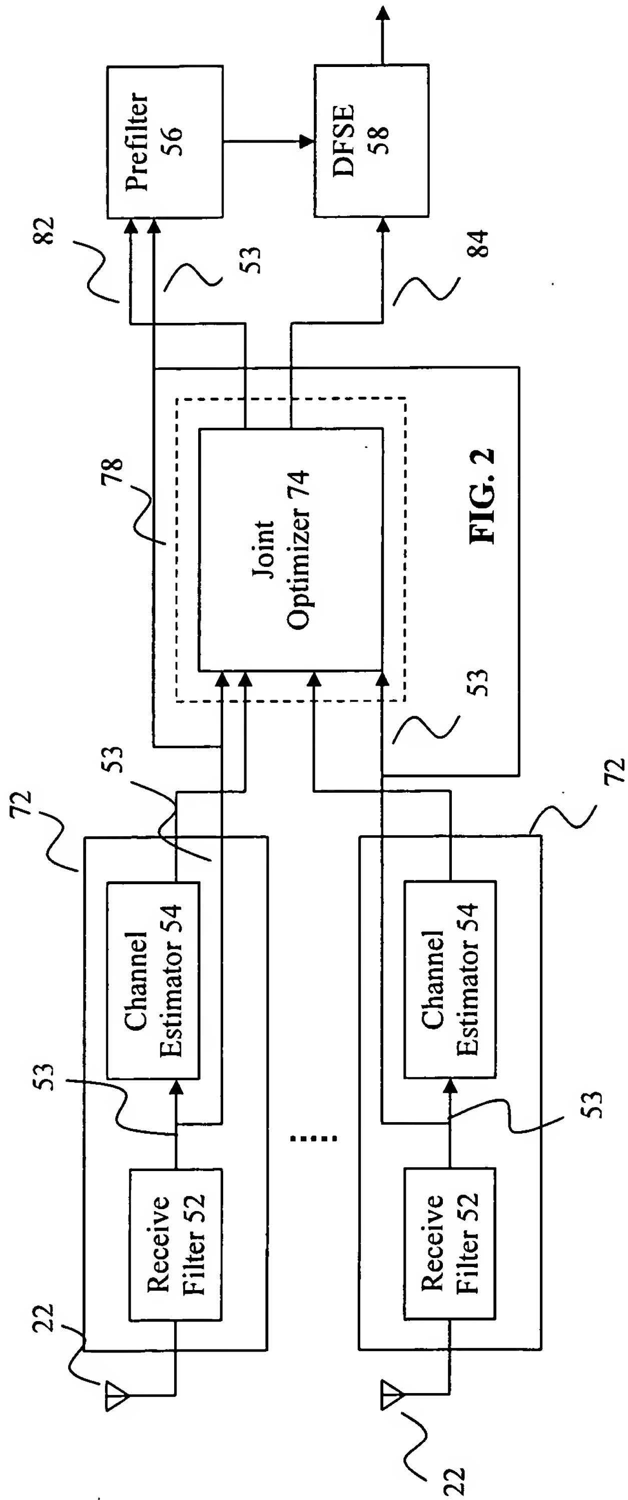
BYC:dlh

Enclosures: Replacement Sheets for Figures 2 and 3


Prefilter 56
DFSE 58
82
53
84
78
Joint Optimizer 74
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72
53
Channel Estimator 54
Channel Estimator 54
53
53
Receive Filter 52
Receive Filter 52
22
22
72

FIG. 2

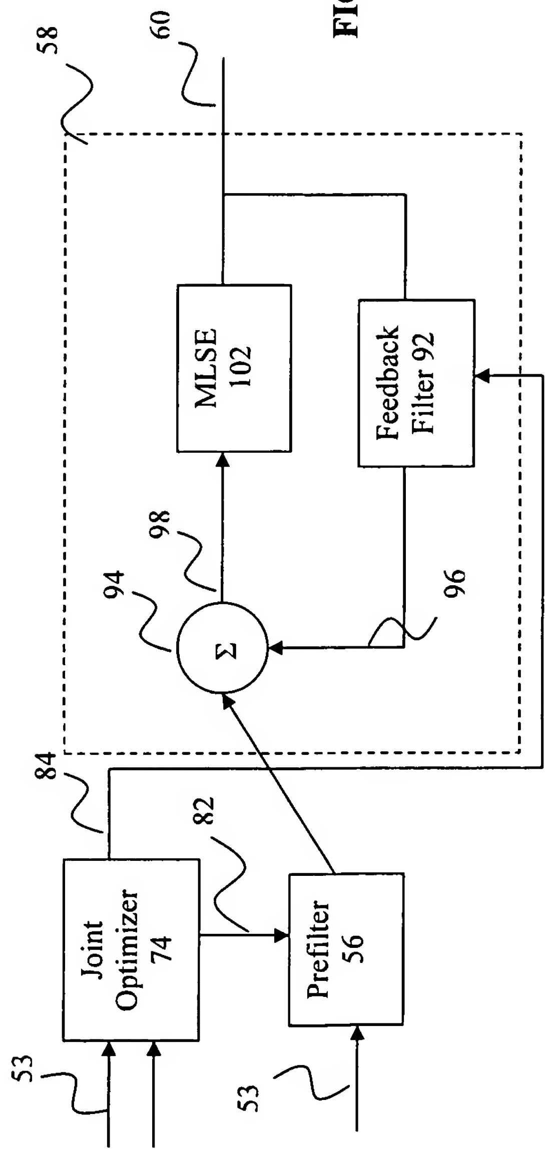
58
60
MLSE
102
Feedback
Filter 92
98
94
Σ
96
84
82
Joint
Optimizer
74
Prefilter
56
53
53

FIG. 3

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APPLICATION NO.	FILING DATE	FIRST NAMED INVENTOR	ATTORNEY DOCKET NO.	CONFIRMATION NO.
10/080,933	02/22/2002	Jianzhong Zhang	059864.00665	6502

32294 7590 04/09/2010
SQUIRE, SANDERS & DEMPSEY L.L.P.
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CORRIELUS, JEAN B	
ART UNIT	**PAPER NUMBER**
2611	
NOTIFICATION DATE	**DELIVERY MODE**
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Please find below and/or attached an Office communication concerning this application or proceeding.

The time period for reply, if any, is set in the attached communication.

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Advisory Action Before the Filing of an Appeal Brief	Application No. 10/080,933	Applicant(s) ZHANG ET AL.
	Examiner Jean B. Corrielus	Art Unit 2611

--The MAILING DATE of this communication appears on the cover sheet with the correspondence address--

THE REPLY FILED 02 April 2010 FAILS TO PLACE THIS APPLICATION IN CONDITION FOR ALLOWANCE.

1. ☒ The reply was filed after a final rejection, but prior to or on the same day as filing a Notice of Appeal. To avoid abandonment of this application, applicant must timely file one of the following replies: (1) an amendment, affidavit, or other evidence, which places the application in condition for allowance; (2) a Notice of Appeal (with appeal fee) in compliance with 37 CFR 41.31; or (3) a Request for Continued Examination (RCE) in compliance with 37 CFR 1.114. The reply must be filed within one of the following time periods:
   a) ☐ The period for reply expires ______months from the mailing date of the final rejection.
   b) ☒ The period for reply expires on: (1) the mailing date of this Advisory Action, or (2) the date set forth in the final rejection, whichever is later. In no event, however, will the statutory period for reply expire later than SIX MONTHS from the mailing date of the final rejection.
   Examiner Note: If box 1 is checked, check either box (a) or (b). ONLY CHECK BOX (b) WHEN THE FIRST REPLY WAS FILED WITHIN TWO MONTHS OF THE FINAL REJECTION. See MPEP 706.07(f).

Extensions of time may be obtained under 37 CFR 1.136(a). The date on which the petition under 37 CFR 1.136(a) and the appropriate extension fee have been filed is the date for purposes of determining the period of extension and the corresponding amount of the fee. The appropriate extension fee under 37 CFR 1.17(a) is calculated from: (1) the expiration date of the shortened statutory period for reply originally set in the final Office action; or (2) as set forth in (b) above, if checked. Any reply received by the Office later than three months after the mailing date of the final rejection, even if timely filed, may reduce any earned patent term adjustment. See 37 CFR 1.704(b).

NOTICE OF APPEAL

2. ☐ The Notice of Appeal was filed on ______. A brief in compliance with 37 CFR 41.37 must be filed within two months of the date of filing the Notice of Appeal (37 CFR 41.37(a)), or any extension thereof (37 CFR 41.37(e)), to avoid dismissal of the appeal. Since a Notice of Appeal has been filed, any reply must be filed within the time period set forth in 37 CFR 41.37(a).

AMENDMENTS

3. ☐ The proposed amendment(s) filed after a final rejection, but prior to the date of filing a brief, will not be entered because
   (a) ☐ They raise new issues that would require further consideration and/or search (see NOTE below);
   (b) ☐ They raise the issue of new matter (see NOTE below);
   (c) ☐ They are not deemed to place the application in better form for appeal by materially reducing or simplifying the issues for appeal; and/or
   (d) ☐ They present additional claims without canceling a corresponding number of finally rejected claims.
   NOTE: ______. (See 37 CFR 1.116 and 41.33(a)).
4. ☐ The amendments are not in compliance with 37 CFR 1.121. See attached Notice of Non-Compliant Amendment (PTOL-324).
5. ☐ Applicant's reply has overcome the following rejection(s): ______.
6. ☐ Newly proposed or amended claim(s) ______ would be allowable if submitted in a separate, timely filed amendment canceling the non-allowable claim(s).
7. ☒ For purposes of appeal, the proposed amendment(s): a) ☐ will not be entered, or b) ☒ will be entered and an explanation of how the new or amended claims would be rejected is provided below or appended.
   The status of the claim(s) is (or will be) as follows:
   Claim(s) allowed: ______.
   Claim(s) objected to: ______.
   Claim(s) rejected: *21,23-28,30-33,36-38,40-42,46 and 47*.
   Claim(s) withdrawn from consideration: ______.

AFFIDAVIT OR OTHER EVIDENCE

8. ☐ The affidavit or other evidence filed after a final action, but before or on the date of filing a Notice of Appeal will not be entered because applicant failed to provide a showing of good and sufficient reasons why the affidavit or other evidence is necessary and was not earlier presented. See 37 CFR 1.116(e).
9. ☐ The affidavit or other evidence filed after the date of filing a Notice of Appeal, but prior to the date of filing a brief, will not be entered because the affidavit or other evidence failed to overcome all rejections under appeal and/or appellant fails to provide a showing a good and sufficient reasons why it is necessary and was not earlier presented. See 37 CFR 41.33(d)(1).
10. ☐ The affidavit or other evidence is entered. An explanation of the status of the claims after entry is below or attached.

REQUEST FOR RECONSIDERATION/OTHER

11. ☒ The request for reconsideration has been considered but does NOT place the application in condition for allowance because: See Continuation Sheet.
12. ☐ Note the attached Information Disclosure Statement(s). (PTO/SB/08) Paper No(s). ______
13. ☒ Other: See Continuation Sheet.

/Jean B Corrielus/
Primary Examiner, Art Unit 2611

Continuation of 11. does NOT place the application in condition for allowance because: the examiner maintains that the prior art renders obvious applicant's invention as claimed (see the final office action).

Continuation of 13. Other: Applicant's arguments with respect to the drawings have been considered but not sufficient to overcome the outstanding drawing objection. With respect to fig. 1, there is no disclosure for a circuit to be connected between channel estimator and prefilter 56. Label "FIG. 2" interfers with the drawing. In addition, page 17, line 7-page 18, line 16, noted by applicant, does not indicate that signal Yk is a signal generated by filter 52 and received by joint optimizer 74.

APPARATUS, AND ASSOCIATED METHOD, FOR A MULTIPLE-INPUT, MULTIPLE-OUTPUT COMMUNICATION SYSTEM

The present invention relates generally to a manner by which to communicate data in a MIMO (multiple-input, multiple-output) communication system. More particularly, the present invention relates to apparatus, and an associated method, by which jointly to perform interference cancellation and equalization prefiltering operations at a receiving station of the communication system. The present invention further relates to a joint encoding, and decoding, scheme for the MIMO communication system. The joint operations are of reduced complexity as the calculations required in their performance increase only linearly, not exponentially, with increases in the number of transmit antennas used in the MIMO communication system. And, the use of the joint encoding and decoding scheme provides improved communication performance of the system at a particular data rate.

BACKGROUND OF THE INVENTION

Data is communicated during operation of a communication system between a sending station and a receiving station by way of a communication channel. Data sourced at the sending station is converted into a form to permit its communication upon the communication channel and then sent thereon. The receiving station detects the data communicated upon the communication channel and operates upon the detected data to recover the informational content thereof.

Many different types of communication systems have been developed and implemented through which to effectuate communication of data pursuant to performance of a communication service.

One exemplary type of communication system is a radio communication system. In a radio communication system, a communication path that connects communication endpoints and upon which a communication channel is defined includes a radio link. The radio link is defined upon a portion of the electromagnetic spectrum. Fixed, wireline connections are not required for the portion of the communication path that is formed of the radio link. The radio communication system is therefore inherently more mobile than a conventional, wireline communication system. The increased mobility results as the sending and receiving stations of a radio communication system are not connected by way of fixed, wireline connections.

A cellular communication system is a type of radio communication system that has achieved wide levels of usage. The networks of various types of cellular communication systems have been installed throughout significant portions of populated areas of the world. A subscriber to a cellular communication system is able to communicate therethrough pursuant to a service subscription for service in the communication system.

The subscriber to the cellular communication system utilizes a mobile station with which to communicate with structure of the network of the cellular communication system. Both the mobile station and the corresponding structure of the network with which the mobile station communicates form radio transceivers capable of both sending and receiving radio signals upon the radio links extending therebetween. Radio transceivers of the network part of a cellular communication system are referred to as base transceiver stations (BTSs) and, as just noted, radio transceivers carried by subscribers to the communication system are typically referred to as mobile stations, due, typically, to their mobility.

The communication channel formed between the communication stations, i.e., the base transceiver station and the mobile station, between which the data is communicated, is non-ideal.

That is to say, the data communicated upon the communication channel is distorted during its propagation between the communication stations. If the distortion is significant, the informational content of the data cannot accurately be recovered once received.

Fading caused by multi-path transmission, for instance, might alter the values of information-bearing bits of the data during its transmission upon the communication channel. Various techniques are utilized to overcome the distortion introduced upon the data.

The redundancy of the transmitted data through time and coding of the data, prior to its transmission, is sometimes utilized to counteract the distortion introduced upon the data during its transmission upon the communication channel. By increasing the time redundancy of the data, the likelihood that the informational content of the data can be recovered, once received at the receiving station, is increased. Introducing time redundancy into the data is sometimes referred to as creating time diversity.

Space diversity is sometimes also utilized to overcome distortion introduced upon the data. Typically, space diversity refers to the utilization of more than one transmit antenna transducer from which data is transmitted, thereby to provide spatial redundancy.

Space and time diversity are sometimes utilized together, thereby further to enhance transmission diversity to combat signal fading caused, e.g., by multi-path transmission.

A receiving station sometimes also utilizes multiple numbers of antennas to facilitate reception of the data transmitted thereto. A communication system in which both multiple transmit antennas and multiple receive antennas are utilized is sometimes referred to as an MIMO (multiple-input, multiple-output) communication system. In such a communication system, independent data streams can be transmitted at different ones of the multiple transmit antennas. And, thereby, the potential throughput of data in such a communication system

increases corresponding with the increase in the number of transmit antennas. That is to say, the potential data throughput increases linearly with the number of transmit antennas that are utilized. To realize the potential data throughput increase permitted through the use of an MIMO system, the receiving station must be able to reliably detect each of the individual data streams in the presence of interference that distorts the data caused both by inter-symbol interference (ISI) and interference caused by other data streams.

Joint detection of the multiple data streams at the receiving station is the optimal approach. However, complexity of equalization operations required to be performed at the receiving station increases exponentially, both with the number of transmit antennas and also with the length of a channel memory. The complexity of equalization operations is so significant as generally to limit the practical utility of such systems in many applications. While use of a properly-designed prefilter can shorten the channel length, and thus reduce the complexity of equalization operations, the complexity required of the equalization operations still limits its suitability for real-time applications.

Alternatively, a much less complex approach to joint detection of the multiple data streams is separate detection of the data streams. During detection of a particular data stream, other data streams are considered to be interference. In this equalization approach, receiver complexity increases only linearly with the number of transmit antennas, rather than the exponential increase resulting in joint detection equalization operations. A multiple step procedure, however, is typically required. That is, a space-time interference cancellation step is first required to be performed and, subsequent thereto, prefiltering/equalization with a decision feedback sequence estimation equalizer structure is performed. The need for use of a multiple-step process is, however, time-consumptive and otherwise disadvantageous.

Improved communication performance would be provided if an improved manner by which to operate upon received data at a receiving station could be provided without increasing the complexity of the receiving station.

Improved communication performance would also be provided if an improved manner by which to encode, and correspondingly decode, the data could be provided.

It is in light of this background information related to communications in an MIMO communication system that the significant improvements of the present invention have evolved.

SUMMARY OF THE INVENTION

The present invention, accordingly, advantageously provides apparatus, and an associated method, by which to communicate data in an MIMO (multiple-input, multiple-output) communication system.

Through operation of an embodiment of the present invention, interference cancellation and decision-feedback-equalization prefiltering operations are performed jointly, thereby to provide single-step performance of such operations.

The joint operations result in reduced complexity as the calculations required in the equalization process increase only linearly with increases in the number of transmit antennas used in the MIMO communication system.

The present invention further advantageously provides a joint encoding, and corresponding decoding, scheme for the MIMO communication system. Use of the joint encoding and decoding schemes provide improved communication performance at a particular data rate when used in a MIMO communication system having a receiving station structure that jointly performs interference cancellation and equalization prefiltering operations.

In one aspect of the present invention, a processing element operates to generate values of parameters to be used by prefilter (feed forward filter) and feedback filter parameters of a decision feedback sequence estimator. The values of the parameters define optimal parameters by which the prefilter and feedback filters are to be operable upon indications of receive data received at the receiving station.

In another aspect of the present invention, separate functional receive chain tags are associated with each receive antenna of the receiving station in the MIMO communication system. Estimated data values of data received at each of the separate receive antennas is provided to the processing element. Values of the optimal feedback filter parameters and values of the optimal feed forward filter parameters are estimated responsive to estimated values of the data received at each of the separate receive antennas.

In another aspect of the present invention, a processing element calculates optimal values of the feed forward and feedback filter parameters, respectively, for each receive chain path. And, separate decision feedback sequence estimators are provided for each receive chain path of the receive station. The separate detected bitstreams are generated by separate ones of the decision feedback sequence estimators of the separate receive chain portions.

Thereby, a low-complexity, MIMO receive structure is provided in which interference cancellation and prefiltering operations are performed jointly, within a common step. Received signal vectors, forming the data communicated to the receive station, are processed by a series of space-time interference canceling and prefiltering filters. Each filter has a target data stream for both suppressing other data streams and for shortening effective channel impulse response of the desired data stream. The resultant structure has a low complexity corresponding to MQ^L wherein

M is the number of transmit antennas, Q is the constellation size of the symbol scheme used in the communication system, and L is the shortened channel memory length.

In one implementation, the prefilter is unbiased. In another implementation, the prefilter is biased.

In another aspect of the present invention, a joint encoding scheme is provided for jointly encoding M-RLC blocks of data that are to be transmitted simultaneously at a sending station by way of M transmitting antennas. Through such joint encoding, improved gain levels can be achieved, as compared to a separate encoding scheme by which the M blocks of data are independently coded.

And, in another aspect of the present invention, a corresponding, decoding scheme is provided for the receive station. Through joint encoding and decoding of the data, improved gain, compared to conventional encoding schemes and corresponding decoding schemes, is provided.

In one implementation, a cellular communication system is implemented as an MIMO system. Base transceiver stations and mobile stations include multiple antenna sets implemented as an MIMO system. Equalization and coding operations are performed to provide improved gain levels of data communication, as well as estimation operations of reduced complexity levels.

In these and other aspects, therefore, apparatus, and an associated method, is provided for a multiple-input, multiple-output communication system. The communication system has a receiving station that receives at least a first data vector transmitted thereto. The data vector is transmitted upon a communication channel, and, when received at the receiving station, the at least the first data vector is formed of received symbols. Operations are performed upon the data

vector, once received at the receiving station. At least a first processing element is coupled to receive indications of the at least the first data vector received at the receiving station. The first processing element forms optimized feed forward filter parameters and optimized feedback filter parameters. The optimized feed forward and feedback filter parameters are used to perform interference cancellation and prefilter operations at the receiving station.

A more complete appreciation of the present invention and the scope thereof can be obtained from the accompanying drawings that are briefly summarized below, the detailed description of the presently preferred embodiments of the invention, and the appended claims.

BRIEF DESCRIPTION OF THE DRAWINGS

Figure 1 illustrates a functional block diagram of an MIMO communication system in which an embodiment of the present invention is operable.

Figure 2 illustrates a functional block diagram of a portion of a receiving station that forms part of the communication system shown in Figure 1.

Figure 3 illustrates another functional block diagram of a portion of the receiving station that forms part of the communication system shown in Figure 1.

Figure 4 illustrates a functional block diagram of a portion of the sending station that forms part of the communication system shown in Figure 1 pursuant to an embodiment of the present invention.

Figure 5 illustrates another functional block diagram of a portion of a receiving station that forms part of the communication system shown in Figure 1 pursuant to an embodiment of the present invention.

Figure 6 illustrates a method flow diagram that lists the method steps of the method of operation of an embodiment of the present invention.

DETAILED DESCRIPTION

Referring first to Figure 1, a communication system, shown generally at 10, provides for communications between remotely-positioned communication stations, here a cellular communication system operable pursuant to a second/third generation (2G/3G) communication standard, such as GSM/GPRS/EGPRS (global system for mobile communication/general packet radio service/enhanced general packet radio service) communication standard. The communication system 10 is representative also of other types of cellular, and other, communication systems. An embodiment of the present invention can, analogously, be implemented in other types of cellular, and other, communication systems, such as a WCDMA (wideband, code-division, multiple-access) communication system, as well as other types of radio, and other, communication systems.

Also, while the following description shall describe operation of the communication system on the forward link, that is, of communication of data by the base transceiver station 14 to the mobile station 12, i.e., in which the base transceiver station forms the sending station and the mobile station 12 forms the receiving station, an embodiment of the present invention can also be implemented in which the mobile station 12 forms the sending station and the base transceiver station 14 forms the receiving station. And, more generally, in any communication system that provides for duplex communications, the communication stations operable pursuant to a communication session are capable both of sending and receiving data, and each communication station operates as both a sending station and a receiving station. Embodiments

of the present invention are implementable at both the transmit and receive parts of the communication stations.

Here, the station 14 includes a plurality of M transmit antennas 18, and the station 12 includes a plurality of N receive antennas 22. Transmit circuitry of the sending station formed of the base transceiver station to be transmitted simultaneously upon the radio link 16. In the exemplary implementation, separate blocks of data are transmitted at separate ones of the transmit antennas 18.

Each receive antenna of the receiving station formed of the mobile station 12 receives indications of the data blocks transmitted at the M transmit antenna 18. In the exemplary implementation, the number N is at least as great as the number M.

Because of the multiple number of transmit antennas permitting parallel transmission of separate data blocks, relatively large data throughput rates are potentially possible during operation of the MIMO system 10. However, because the receive antenna 22 of the receiving station receives data transmitted by each of the transmit antennas, significant processing is required at the receive station to recover the informational content of the data sent by each of the separate antennas. Operation of an embodiment of the present invention provides a manner by which to facilitate recovery of the informational content of the data transmitted by the separate transmit antennas that necessitate only relatively low-complexity processing at the receive station.

Functional elements of the sending station formed of the base transceiver station 14 include a channel encoder 28, coupled to the lines 26 to receive indications of the data that is to be sent to the receiving station. The channel encoder encodes the data and provides the data to a puncturer 32 that operates to puncture selected portions of the encoded data. And, the puncturer

is coupled to an interleaver 34 that operates to interleave selected parts of the encoded, punctured data provided thereto. And, as indicated by the block 38, data formatting, pulse shaping, and symbol assigning functions are performed to convert the data into form to facilitate its communication by way of the radio link 16 to the receiving station. The element 38 is coupled to the transmit antennas 18.

The receiving station also includes functional elements that operate upon data detected by the receive antennas 22. A receive filter is coupled to the receive antennas to at least suppress out-of-band interference. Subsequent to receive filtering of the data at the receive filter 52, channel estimation operations are performed by the channel estimator 54. Estimated values are prefiltered by a prefilter 56. And, once prefiltered, the data is estimated by a direct feedback, sequence estimator (DFSE) 58 and thereafter de-interleaved by a de-interleaver 60, de-punctured by a de-puncturer 62, and decoded by a channel decoder 64.

An embodiment of the present invention is implemented at the receive station to facilitate recovery of the informational content of the data transmitted by the plurality of transmit antennas upon the radio link to the receive station. A lowered-complexity structure, relative to conventional manners by which to operate upon the data, is provided. Lowered-complexity calculations are performed to perform interference cancellation operations and to perform prefiltering operations at an MMSE-DFE prefilter. Through operation of an embodiment of the present invention, data streams are detected individually rather than jointly, and, in terms of algorithm performance, improvement is achieved by joint interference cancellation and prefiltering.

Figure 2 illustrates a portion of the receiving station formed of the mobile station 12 of the communication system 10 shown in Figure 1. Here, separate receive chain portions 72,

associated with each of the receive antennas 22. And, part of an additional receive chain portion is also shown. Other receive chain portions can analogously be represented.

With respect to the top-most (as shown) receive chain portion 72, coupled to a top-most (as shown) receive antenna 22, the received data is filtered by a receive filter 52. Here, the functionality of the receive filters are separately represented at each of the receive chain portions. Again, subsequent to receive filtering operations performed upon the detected data, joint channel estimation is performed by a channel estimator 54. The channel estimator performs channel estimation functions and, thereafter, values are provided to a joint optimizer 74. Other receive chain portions of the receiving station also include corresponding joint optimizer and are coupled to receive indications of values formed by the channel estimator. And, correspondingly, other receive chain portions provide indications of channel estimations performed at such other receive chain portions to the joint optimizer 74 of the top-most (as shown) receive chain portion. The joint optimizer 74 of the receive chain portion define the apparatus 78 of an embodiment of the present invention. Each joint optimizer operates, in manners that shall be described in greater detail below, to generate optimal parameter values to be used for subsequent operations at the receive chain portion.

Here, the joint optimizer 74 generates optimal parameter values on the lines 82 and 84. Other processing elements of other receive chain portions analogously generate corresponding optimal parameter values for use at other such receive chain portions.

Values generated by the joint optimizer 74 on the lines 82 and 84 are provided to a prefilter and decision feedback sequence estimator 56/58. Other receive chain portions analogously include corresponding functional elements to which corresponding values formed by corresponding joint optimizer are applied.

Figure 3 again illustrates the joint optimizer 74 and the lines 82 and 84 upon which optimal parameter values, calculated at the processing element are here shown to be provided to a prefilter 56 and a feedback filter 92, respectively. Values representative of the data detected at the receive antenna 22, and filtered by a receive filter on the lines 53 are also shown to be provided to the prefilter. Prefiltering operations are performed upon the representations of the data provided thereto on the lines 53 in which the filter characteristics of the prefilter are determined by values of the optimal feedforward prefilter characteristics generated on the lines 82.

Prefiltered values are provided to the decision feedback sequence estimator 58. And, more particularly, the values provided to the DFSE are summed thereat, indicated at the summing element 94 together with values generated by the feedback filter 92 on the line 96. Summed values are generated on the line 98 and provided to an MLSE (maximum likelihood sequence estimator) 102. Maximum-likelihood values are generated on the line 60, and the line 60 extends to other receive chain portion elements (not shown) and to the feedback filter 92. The filter characteristics of the feedback filter are defined by the optimal parameter values provided thereto on the line 84. The feedback filter operates to filter the values provided thereto on the line 60 and to generate feedback-filtered values on the line 96. Operation of the joint optimizer 74 at the separate receive chain portions are represented mathematically below wherein the following designations are utilized:

M:	number of transmit antennas,
N:	number of receive antennas,
$L+1$:	length of the channel impulse response
$K+1$:	length of the canceling/prefiltering filter length

S:	over-sampling rate, 2 or 4,
x:	transmitted symbols,
y:	over-sampled signal vector at the output of receive filter,
h:	channel impulse response (includes transmit filter, receive filter and physical channel),
w_f:	space-time interference cancellation filter,
w_b:	feed-forward filter
z:	symbol spaced signal vector at the output of the space-time filter

In the baseband part of a receive chain, the over-sampled received signal vector at the output of an anti-aliasing filter at a receive antenna 22 and time k is:

$$\hat{\mathbf{y}}_{n,k} = \sum_{l=0}^{L} \sum_{m=1}^{M} \mathbf{h}_{n,m,l} x_{m,k-l} + \mathbf{n}_{n,k} \qquad n=1,\ldots,N$$

Where $\hat{\mathbf{y}}_{n,k} = [y_{n,k,1}, \ldots y_{n,k,S}]^T$ is the over-sampled received signal vector and $\mathbf{h}_{n,m,l} = [h_{n,m,l,1}, \ldots h_{n,m,l,S}]^T$ is the over-sampled lth tap channel coefficient between nth receive and mth transmit antenna 18. Meanwhile, S is the over-sampling rate and $x_{m,k}$ is the transmitted symbol at transmit antenna m and time k.

Since space-time filtering operates across all the receive antennas with a temporal memory of K+1, the sampled received vectors can be represented in the following manner:

$$\mathbf{y}_k = \begin{bmatrix} \hat{\mathbf{y}}_{k+K} \\ \hat{\mathbf{y}}_{k+K-1} \\ \vdots \\ \hat{\mathbf{y}}_k \end{bmatrix} = \sum_{m=1}^{M} \begin{bmatrix} \hat{\mathbf{h}}_{m,0} & \cdots & \hat{\mathbf{h}}_{m,L} & & \\ & \hat{\mathbf{h}}_{m,0} & & \hat{\mathbf{h}}_{m,L} & \\ & & \ddots & & \ddots \\ & & & \hat{\mathbf{h}}_{m,0} & \cdots \hat{\mathbf{h}}_{m,L} \end{bmatrix} \begin{bmatrix} x_{m,k+K} \\ x_{m,k+K-1} \\ \vdots \\ x_{m,k-L} \end{bmatrix} + \begin{bmatrix} \mathbf{n}_{k+K} \\ \mathbf{n}_{k+K-1} \\ \vdots \\ \mathbf{n}_k \end{bmatrix}$$

$$\triangleq \sum_{m=1}^{M} \mathbf{H}_m \mathbf{x}_{m,k} + \mathbf{n}_k$$

where $\hat{\mathbf{y}}_k = \left[\hat{\mathbf{y}}_{1,k}^T, \ldots, \hat{\mathbf{y}}_{N,k}^T\right]^T$ is the over-sampled received vector across all received antennas at time k, and $\hat{\mathbf{h}}_{m,l} = \left[\mathbf{h}_{1,m,l}^T, \ldots, \mathbf{h}_{N,m,l}^T\right]^T$ is the over-sampled *lth* tap channel coefficients across all receive antennas for the channels originated from the *mth* transmit antenna.

There will be a total of M space-time filters, each producing an output stream $\mathbf{z}_m$ that contains the signal part of $\mathbf{x}_m$ with shortened effective channel impulse response and the suppressed interference $\mathbf{x}_p, p \neq m$, x_1 is the desired signal and derive the space-time filter $\mathbf{w}_{f1}$.

An MMSE-DFE structure of the prefilter/equlier pair is shown in Figure 3. There are two filters: the feedforward filter 56 which is the space-time prefilter $\mathbf{w}_{f1}$ and the feedback filter 92 $\mathbf{w}_{b1}$. At time k, the signal at the input of the MLSE equalizers is:

$$z_{1,k} = \mathbf{w}_{f1}^H \mathbf{y}_k - \mathbf{w}_{b1}^H \mathbf{x}_{1,k,p}$$

Where $\mathbf{y}_k$ is defined as above and $\mathbf{x}_{q,k,p} = \left[x_{1,k-1}, \ldots, x_{1,k-L}\right]^T$ is the previously detected symbols at time k where *'p'* stands for 'pre-cursor'. Note in mathematical analysis, perfect feedback is assumed, i.e., all the previously detected symbols are correct. Minimizing the mean square error (MSE) between $z_{1,k}$ and $x_{1,k}$ is, to this end, the optimal, designated by "t" prefilter $\mathbf{w}_{b1}$ can be obtained by:

$$\mathbf{w}_{f1}^{+}, \mathbf{w}_{b1}^{+} = \arg \min_{w_{f1} w_{b1}} E\left\| z_{1,k} - x_{1,k} \right\|^2 = \arg \min_{w_{f1} w_{bq}} E\left\| w_{f1}^H \mathbf{y}_k - \mathbf{w}_{b1}^H \mathbf{x}_{1,k,p} - x_{1,k} \right\|^2.$$

The Wiener filter approach is herein. First, an above-listed equation is rewritten as follows:

$$y_k = \mathbf{H}_{1,p} x_{1,k,p} + \mathbf{H}_{1,c} x_{1,k,c} + \sum_{m=2}^{M} \mathbf{H}_m x_{m,k} + \mathbf{n}_k$$

where $x_{1,k,p}$ is defined as above and $x_{1,k,c} = \left[x_{1,k+K} \cdots x_{1,k}\right]^T$ is the causal part of the input data vector. Accordingly, $\mathbf{H}_{1,p}$ and $\mathbf{H}_{1,c}$ are the corresponding pre-cursor and causal parts of channel

matrices. That is, $\mathbf{H}_1 = \lfloor \mathbf{H}_{1,c} \mathbf{H}_{1,p} \rfloor$ and $x_{1,k} = \lfloor x_{1,k,c}^T x_{1,k,p}^T \rfloor^T$. Substitution into the above equation obtains the following:

$$\mathbf{w}_{f1}^{+}, \mathbf{w}_{b1}^{+} = \arg \min_{w} \mathrm{E} \left\| \left[\mathbf{w}_{f1}^{H} \middle| \mathbf{w}_{b1}^{H} \right] \begin{bmatrix} \mathbf{H}_{1,c}\mathbf{x}_{1,k,c} + \mathbf{H}_{1,p}\mathbf{x}_{1,k,p} + \sum_{m=2}^{M} \mathbf{H}_m \mathbf{x}_{m,k} + \mathbf{n}_k \\ \hline -\mathbf{x}_{1,k,p} \end{bmatrix} - x_{1,k} \right\|^2$$

$$\triangleq \arg \min_{w_{f1} w_{b1}} \mathrm{E} \left\| \mathbf{w}^H \mathbf{s} - x_{1,k} \right\|^2$$

which is in the standard form of Wiener-Hopf filtering problem and the solution is given by the set of linear equations

$$E\lfloor ss^H \rfloor w = E\lfloor x_{1,k}^{*} s \rfloor.$$

In order to obtain the correlation matrices in the above equation, statistical knowledge about the transmitted data streams and the noise is required. Without loss of generality, all of the data streams are assumed to be statistically independent and all the symbols are normalized random I.I.D within a data stream. Furthermore, the noise is assumed to be independent from data symbols. With these assumptions, the correlation matrices are computed, and an above-listed equation is expanded as:

$$\left[\begin{array}{c|c} \mathbf{H}_{1,c}\mathbf{H}_{1,c}^{H} + \mathbf{H}_{1,p}\mathbf{H}_{1,p}^{H} + \sum_{m=2}^{M} \mathbf{H}_m \mathbf{H}_m^H + \mathbf{R}_{nn} & -\mathbf{H}_{1,p} \\ \hline -\mathbf{H}_{1,p}^{H} & I \end{array}\right] \begin{bmatrix} \mathbf{w}_{f1} \\ \hline \mathbf{w}_{b1} \end{bmatrix} = \begin{bmatrix} \tilde{\mathbf{h}}_1 \\ \hline 0 \end{bmatrix}$$

Where $\tilde{\mathbf{h}}_1$ is the (L+1)th column in the matrix $\mathbf{H}_1$ counting from right and $\mathbf{R}_{nn} = E\lfloor \mathbf{n}_k \mathbf{n}_k^H \rfloor$ is the noise correlation matrix. Now the optimal filter of the biased design can be easily given as:

$$\mathbf{w}_{f1,B}^{+} = \left[\mathbf{H}_{1,c}\mathbf{H}_{1,c}^{H} + \sum_{m=2}^{M} \mathbf{H}_m \mathbf{H}_m^H + \mathbf{R}_{nn} \right]^{-1} \tilde{\mathbf{h}}_1$$

$$\mathbf{w}_{bl,B}^{+} = \mathbf{H}_{1,p}^{H} \mathbf{w}_{f1}$$

The MMSE-DFE prefilter 56, in one implementation, is biased. An easy way to see the bias is to observe that the MSE between the filter output $z_{1,k}$ and the input symbol $x_{1,k}$ is minimized. However, after the filter optimization the signal component in $z_{1,k}$ is scaled by $\mathbf{w}_{f1}\mathbf{h}_1$ which is not of a value of 1 in general. Here we propose an unbiased MMSE-DFE prefilter with linear constraint to remove the bias. It can be analytically shown that the output SNR (OSNR) of the unbiased prefilter is the same as the biased prefilter, if the output SNR is properly defined.

To derive the unbiased MMSE-DFE prefilter, a linear constraint is used to make sure the bias is removed in the output signal:

$$\mathbf{w}_{f1}^{+},\mathbf{w}_{b1}^{+} = \arg\min_{w_{f1}w_{b1}} \mathrm{E}\left\| z_{1,k} - x_{1,k} \right\|^2 = \arg\min_{w_{f1}w_{bq}} E\left\| \mathbf{w}_{f1}^H \mathbf{y}_k - \mathbf{w}_{b1}^H \mathbf{x}_{1,k,p} - x_{1,k} \right\|^2$$

$$s.t. \quad \mathbf{w}_{f1}^H \tilde{\mathbf{h}}_1 = 1$$

where $\mathbf{h}_1$ is defined above. Lagrange multipliers are used to obtain a solution. To facilitate the derivation, the causal part of input symbols $\mathbf{x}_{1,k,c}$ is broken into two parts: $\mathbf{x}_{1,k,c} = \left[x_{1,k,a}^T; x_{1,k}\right]^T$ where $x_{1,k}$ is the current symbol and $\mathbf{x}_{1,k,a} = [x_{k+K}, \ldots x_{k+1}]^T$ is the post-cursor part of the input symbols. Accordingly, we have $\mathbf{H}_{1,c} = [\mathbf{H}_{1,a}, \mathbf{h}_1]$ where $\mathbf{H}_{1,a}$ and $\mathbf{h}_1$ are the corresponding channel matrices for the post-cursor input symbols and the current data symbol. Now the equation can be rewritten as:

$$\mathbf{y}_k = \mathbf{H}_{1,p}\mathbf{x}_{1,k,p} + \mathbf{H}_{1,c}\mathbf{x}_{1,k,a} + \tilde{\mathbf{h}}_1 \mathbf{x}_{1,k} + \sum_{m=2}^{M} \mathbf{H}_m \mathbf{x}_{m,k} + \mathbf{n}_k$$

Substituting the equation and the linear constraint into the MSE expression, the following is obtained:

$$J \triangleq E\left\| \mathbf{w}_{f1}^H \mathbf{y}_k - \mathbf{w}_{b1}^H \mathbf{x}_{1,k,p} - x_{1,k} \right\|^2$$

$$=E\left\|(\mathbf{w}_{f1}^{H}\mathbf{H}_{1,p}-\mathbf{w}_{b1}^{H})\mathbf{x}_{1,k,p}+\mathbf{w}_{f1}^{H}(\mathbf{H}_{1,a}\mathbf{x}_{1,k,a}+\sum_{m=2}^{M}\mathbf{H}_{m}\mathbf{x}_{m,k}+\mathbf{n}_{k})\right\|^{2}$$

$$=\left\|\mathbf{w}_{f1}^{H}\mathbf{H}_{1,p}-\mathbf{w}_{b1}^{H}\right\|^{2}+\mathbf{w}_{f1}^{H}(\mathbf{H}_{1,a}\mathbf{H}_{1,a}^{H}+\sum_{m=2}^{M}\mathbf{H}_{m}\mathbf{H}_{m}^{H}+\mathbf{R}_{n,n})\mathbf{w}_{f1}$$

The same statistical properties of the variables are used as in the biased case. In order to minimize the MSE, it is easy to see that the first term is advantageously taken to zero to be zero, i.e. $\mathbf{w}_{b1} = \mathbf{H}^{H}{}_{1,p}\mathbf{w}_{f1}$. By setting

$$\mathbf{V}\triangleq\mathbf{H}_{1,a}\mathbf{H}_{1,a}^{H}+\sum_{m=2}^{M}\mathbf{H}_{m}\mathbf{H}_{m}^{H}+\mathbf{R}_{n,n}$$

the optimization of $\mathbf{w}_{f1}$ is reduced into:

$$\mathbf{w}_{f1}^{+}=\arg\min_{w_{f1}}\mathbf{w}_{f1}^{H}\mathbf{V}\mathbf{w}_{f1}\quad s.t.\quad \mathbf{w}_{f1}^{H}\tilde{\mathbf{h}}_{1}=1$$

which can be easily solved by the Lagrange Multiplier method and the optimal solution is given by:

$$\mathbf{w}_{f1,U}^{+} = \mathbf{V}^{-1}\tilde{\mathbf{h}}_{1}(\tilde{\mathbf{h}}_{1}^{H}\mathbf{V}^{-1}\tilde{\mathbf{h}}_{1})^{-1}$$

$$\mathbf{w}_{b1,U}^{+} = \mathbf{H}_{1,p}^{H}\mathbf{w}_{f1}$$

The output signal to noise ratio (OSNR) is defined as the ratio of signal strength versus the noise and residue interference strength after prefiltering:

$$OSNR = \frac{E\left\|\mathbf{w}_{f1}^{H}\tilde{\mathbf{h}}_{1}x_{1,k}\right\|^{2}}{E\left\|z_{1,k}-\mathbf{w}_{f1}^{H}\tilde{\mathbf{h}}_{1}x_{1,k}\right\|^{2}}$$

Upon analysis, both biased and unbiased prefilter can be shown to be substantially similar.

Figure 4 illustrates a functional block diagram of apparatus of an embodiment of the present invention formed at the sending station 14 of the communication system 10 shown in

Figure 1. Here, M separate RLC blocks of data, indicated by the blocks 112, that are provided to a multiplexer 114 that generates multiplexed values on the lines 28 that are provided to a joint encoder 26. The joint encoder jointly encodes the data of each of the M blocks jointly. The jointly-encoded data is provided to a data puncturer 32 that performs selected puncturing operations upon the jointly-encoded data. And, an interleaver 34 interleaves values of the data provided thereto. Once interleaved, the data is demultiplexed by a demultiplexer 118. Once demultiplexed, separate lines 122 extend to separate subsequent blocks 38 of the sending station. And, thereafter, to each of the M transmit antennas 18.

Figure 5 illustrates corresponding structure positioned at the receiving station that operates to decode the jointly encoded data of the sending station 14 of the implementation shown in Figure 4. Here, the receive antennas 22 again convert received data into electrical form and provide indications thereof to receive filter elements, here designated at 122. The receive filter elements generate filtered indications of the received data and provide such indications to a joint channel estimator 124. Joint estimations are performed responsive to all of the detected data on each of the receive antennas. Indications thereof are provided to separate space-time prefilter elements 126 and, thereafter, indications are provided to SISO (single input, single output) equalizer elements 128. The values generated by the separate equalizer elements are multiplexed together by a multiplexer 132. The multiplexed values are provided to a joint turbo decoder 134 (by turbo decoder we mean any decoder that iteratively passes soft information between decoding modules) that turbo-decodes the joint values. Decoded values are generated on the line 136, provided to an element 138 that removes tailbits out of the formatted data. Thereafter, the data is demultiplexed by a demultiplexer 142 and separate, demultiplexed, output values are generated on the lines 144.

Figure 6 illustrates a method, shown generally at 152, of an embodiment of the present invention. The method is operable in a multiple-input, multiple-output communication system having a receiving station that receives at least a first data vector. The method operates upon the data vector, once received at the receiving station.

First, and as indicated by the block 154, optimized feedforward filter parameters and optimized feedback filter parameters are formed. Then, and as indicated by the block 156, the optimized feedforward filter parameters are applied to a feedforward filter to define filter characteristics of the feedforward filter. And, as indicated by the block 158, the optimized feedback parameters are applied to a feedback filter to define the filter characteristics of the feedback filter.

Then, and as indicated by the block 162, interference cancellation and prefiltering operations are concurrently performed through operation of the prefilter 56 and DFSE 58.

The previous descriptions are of preferred examples for implementing the invention, and the scope of the invention should not necessarily be limited by this description. The scope of the present invention is defined by the following claims:

In the claims:

1. In a multiple-input, multiple-output communication system having a receiving station that receives at least a first data vector transmitted thereto upon a communication channel, the at least the first data vector formed of received symbols, an improvement of apparatus for operating upon the data vector, once received at the receiving station, said apparatus comprising:

at least a first processing element coupled to receive indications of the at least the first data vector received at the receiving station, said first processing element for forming optimized feedforward filter parameters and optimized feedback filter parameters, the optimized feedforward and feedback filter parameters used to perform interference cancellation and prefilter operations at the receiving station.

2. The apparatus of claim 1 wherein the receiving station further comprises at least a first feedforward filter coupled to receive indications of the at least the first data vector, wherein said first processing element is coupled to the first feedforward filter, and wherein the optimized feedforward filter parameters formed by said first processing element are provided to the first feedforward filter, values of the optimized feedforward parameters used at the first feedforward filter to define filter characteristics of the first feedforward filter and feedforward filtering operations performed upon the indications of the first data vector.

3. The apparatus of claim 2 wherein the at least the first data vector comprises the first data vector and at least a second data vector, wherein said at least the first processing element comprises the first processing element and at least a second processing element, wherein

the at least the first feedforward filter comprises the first feedforward filter and at least a second feedforward filter, said second processing element coupled to the second feedforward filter, optimized feedforward parameters formed by said second processing element provided to the second feedforward filter, values thereof used at the second feedforward filter to define filter characteristics of the second feedforward filter.

4. The apparatus of claim 1 wherein the receiving station further comprises at least a first feedback filter coupled to receive indications of the at least the first data vector, wherein said first processing element is coupled to the first feedback filter, and wherein the optimized feedback filter parameters formed by said first processing element are provided to the first feedback filter, values of the optimized feedback parameters used at the first feedback filter to define filter characteristics thereof.

5. The apparatus of claim 4 wherein the at least the first data vector comprises the first data vector and at least a second data vector, wherein said at least the first processing element comprises said first processing element and at least a second processing element, wherein the at least the first feedback filter comprises the first feedback filter and at least the second feedback filter, said second processing element coupled to the second feedback filter, optimized feedback parameters formed by said second processing element provided to the second feedback filter, values thereof used at the second feedback filter to define filter characteristics of the second feedforward filter.

6. The apparatus of claim 4 wherein the receiving station further comprises at least a first feedforward filter coupled to received values representative of the first data vector, wherein said first processing element is coupled to the first feedforward filter and wherein the optimized feedforward filter parameters formed by said first processing element are provided to the first feedforward filter, values of the optimized feedforward parameters used at the first feedforward filter to define filter characteristics of the first feedforward filter, the first feedforward filter forming a first feedforward-filtered signal, the first feedforward-filtered signal forming the indications of the at least the first data vector.

7. The apparatus of claim 6 wherein the receiving station further comprises a sequence estimator and wherein the first feedback filter to which the optimized feedback parameters formed by said first processing element are provided form part of the sequence estimator.

8. The apparatus of claim 7 wherein the first feedforward filter to which the optimized feedforward parameters are provided by said first processing element form part of the sequence estimator.

9. The apparatus of claim 8 wherein application of the optimized feedforward and feedback parameters, respectively, to the feedforward and feedback filters, respectively, permits concurrent interference cancellation and prefilter operations to be performed at the sequence estimator.

10. The apparatus of claim 8 wherein the sequence estimator to which the feedforward and feedback parameters are provided by said first processing element comprises a decision feedback sequence estimator having a maximum likelihood sequence estimator to which the feedback filter is connected in a feedback arrangement.

11. The apparatus of claim 1 wherein the receiving station comprises a plurality of receive antenna elements and wherein said at least first processing element comprises a plurality of processing elements, said plurality of processing elements at least corresponding in number with the plurality of receive elements.

12. The apparatus of claim 11 wherein the receiving station is further comprised of a plurality of receive-chain portions, the plurality of receive-chain portions corresponding in number with the number of processing elements of said plurality of processing elements, a processing element of said plurality of processing elements forming part of each receive chain of the plurality of receive chains.

13. In the multiple-input, multiple-output communication system of claim 1 wherein the at least the first data vector is transmitted to the receiving station by a sending station, a further improvement of apparatus for the communication system, said apparatus comprising:

a joint encoder coupled to data that is to be sent to the receiving station, the send data formed of at least a first and a second data sequence, said joint encoder for jointly encoding the at least the first and second data sequences.

14. The further apparatus of claim 13 wherein said joint encoder further comprises a data puncturer for puncturing the encoded data encoded thereat.

15. The further apparatus of claim 14 wherein said joint encoder further comprises an interleaver for interleaving the encoded punctured data thereat.

16. In the multiple-input, multiple-output communication system of claim 15 wherein the apparatus for operating upon the data vector, once received at the receiving station, further comprises a joint decoder for performing joint decoding operations upon data representative of at least the first data vector.

17. In a method of communicating in a multiple-input, multiple-output communication system having a receiving station that receives at least a first data vector and transmitted thereto upon a communication channel, the at least the first data vector formed of received symbols, an improvement of a method for operating upon the data vector, once received at the receiving station, said method comprising:

forming optimized feedforward filter parameters and optimized feedback filter parameters;

applying the optimized feedforward filter parameters to a feedforward filter to define filter characteristics of the feedforward filter;

applying the optimized feedback filter parameters to a feedback filter to define filter characteristics of the feedback filter; and

concurrently performing interference cancellation and prefiltering operations through operation of the feedforward and feedback filters, respectively.

18. The method of claim 17 further comprising the operations, prior to said operation of forming, of:

jointly encoding input data at the sending station; and

transmitting the data, once encoded, to the receiving station.

19. The method of claim 18 comprising the further operation of jointly decoding indications of the at least the first data vector subsequent to performance of interference cancellation and prefiltering operations.

20. The method of claim 19 wherein said operation of concurrently performing the interference cancellation and prefiltering is performed at a decision feedback sequence estimator.

ABSTRACT

Apparatus, and an associated method, for a multiple-input, multiple-output communication system having M transmit antennas and N receive antennas. Apparatus is provided for the receiving station including processing elements permitting joint interference cancellation and prefiltering of data received at the receiving station. Additional joint encoding apparatus is provided for a sending station of the MIMO communication system together with corresponding decoding apparatus of the receiving station.

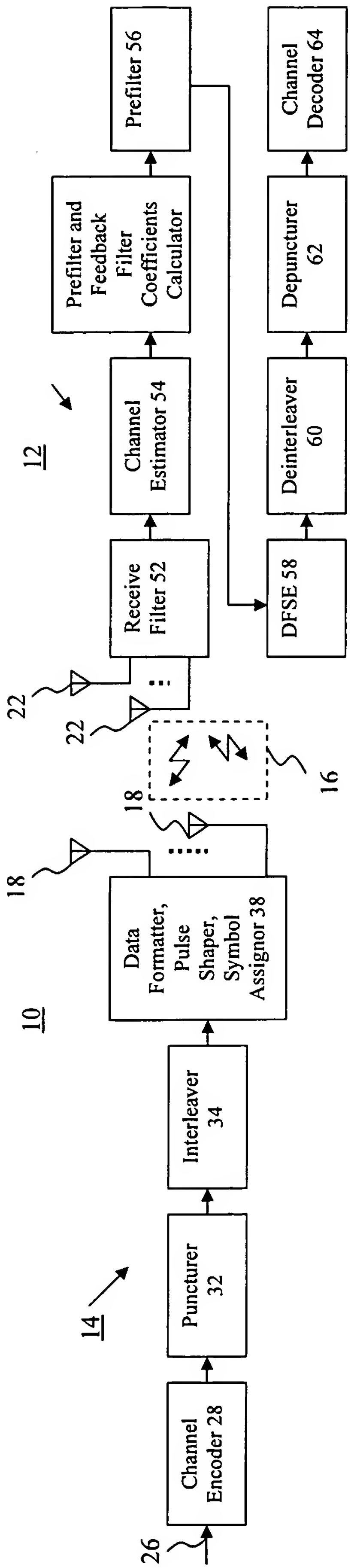
26
Channel Encoder 28
14
Puncturer 32
Interleaver 34
10
Data Formatter, Pulse Shaper, Symbol Assignor 38
18
18
16
22
22
Receive Filter 52
12
Channel Estimator 54
Prefilter and Feedback Filter Coefficients Calculator
Prefilter 56
DFSE 58
Deinterleaver 60
Depuncturer 62
Channel Decoder 64

FIG. 1

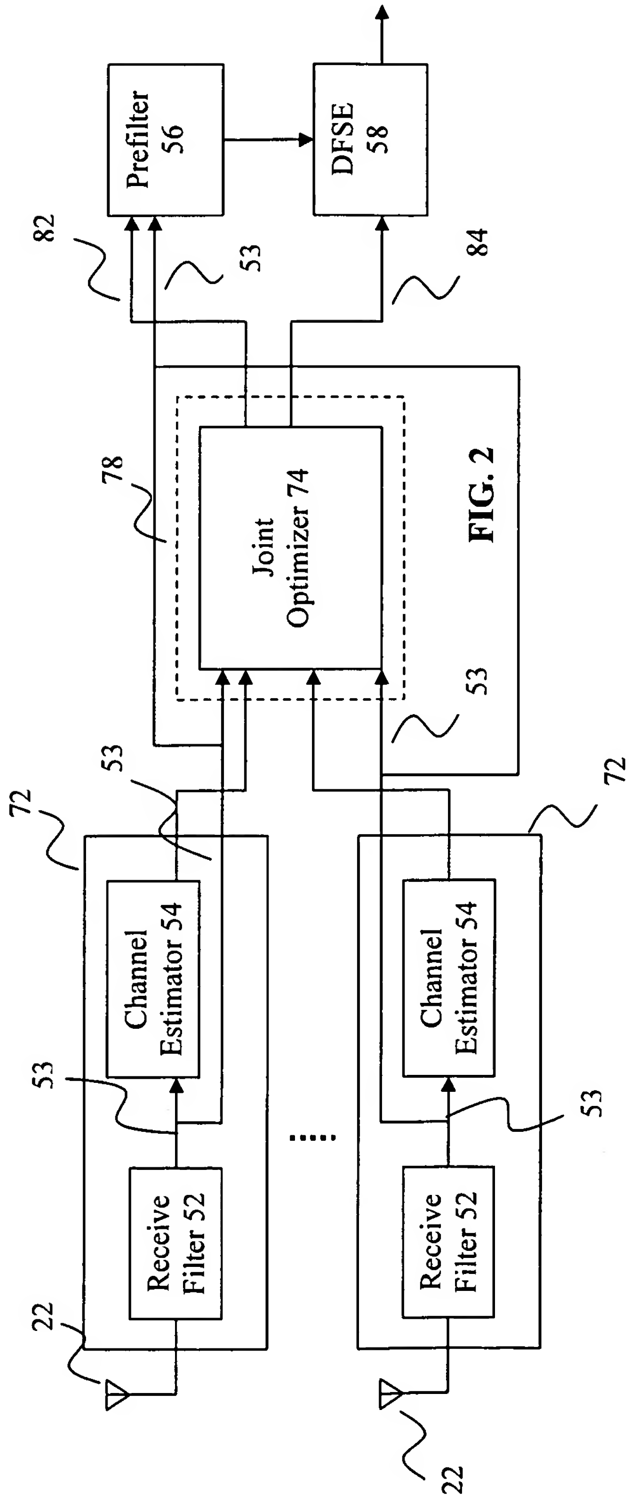
Prefilter 56
DFSE 58
82
53
84
78
Joint Optimizer 74
53
53
72
72
Channel Estimator 54
Channel Estimator 54
53
53
Receive Filter 52
Receive Filter 52
22
22

FIG. 2

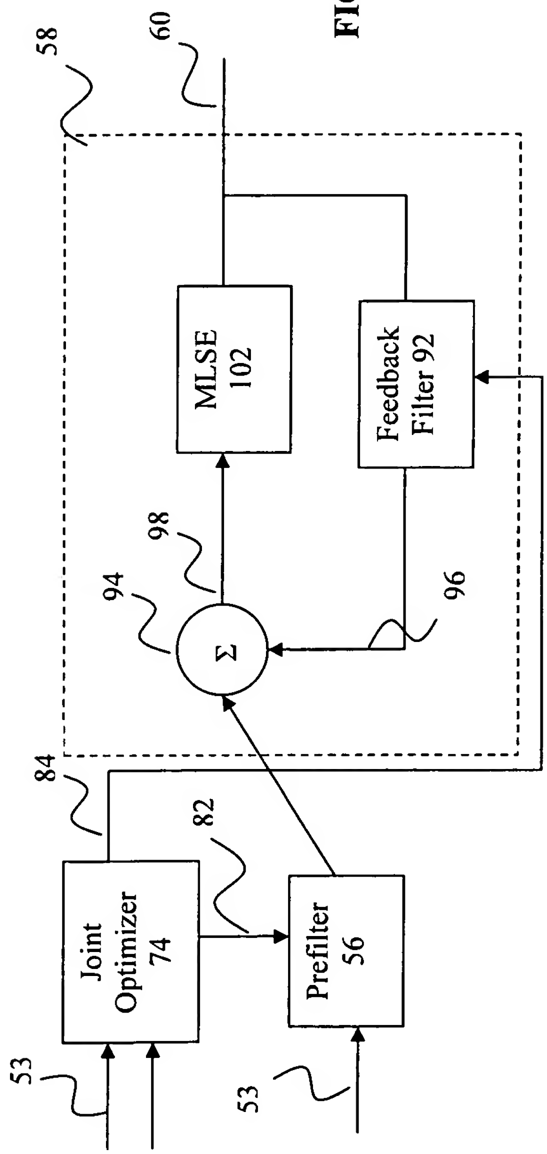
58
60
MLSE
102
Feedback
Filter 92
98
94
Σ
96
84
82
Joint
Optimizer
74
Prefilter
56
53
53

FIG. 3